

# SOONER OR LATER

## Shifting the timing of electricity demand

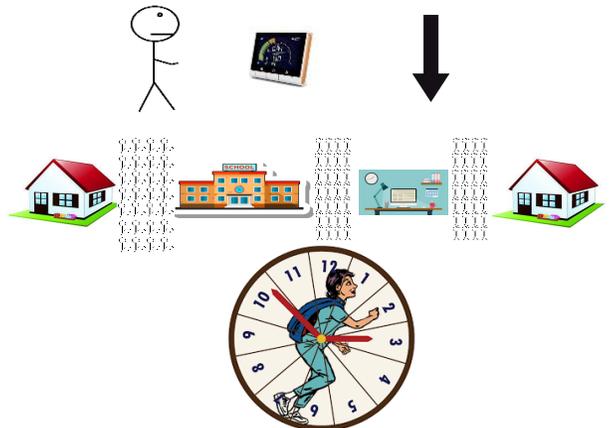
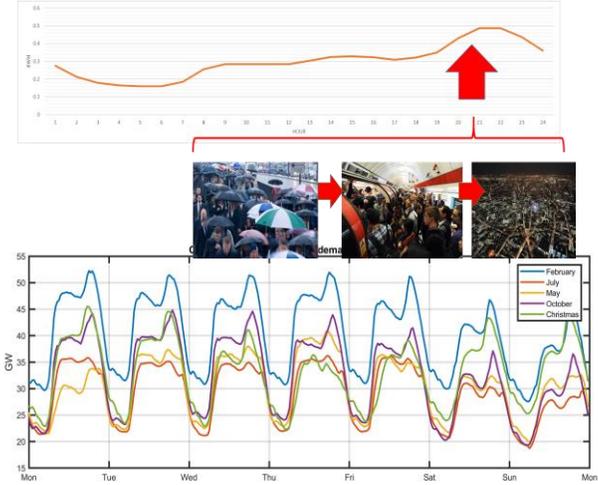


Professor Jacopo Torriti

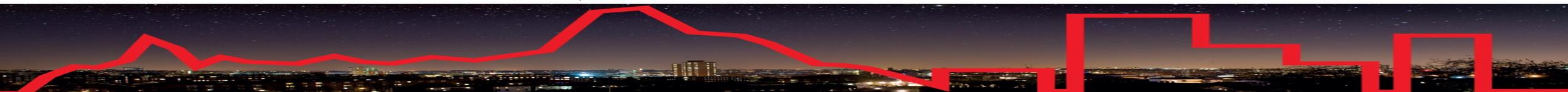
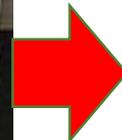
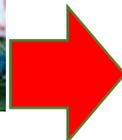
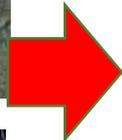
15<sup>th</sup> May 2019

# Outline

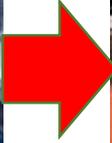
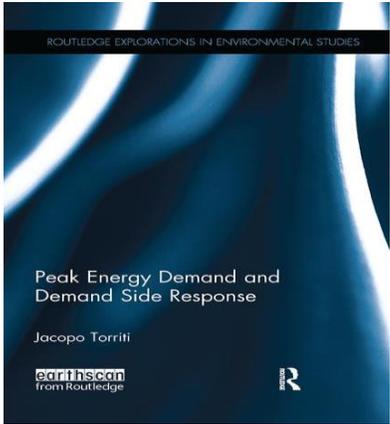
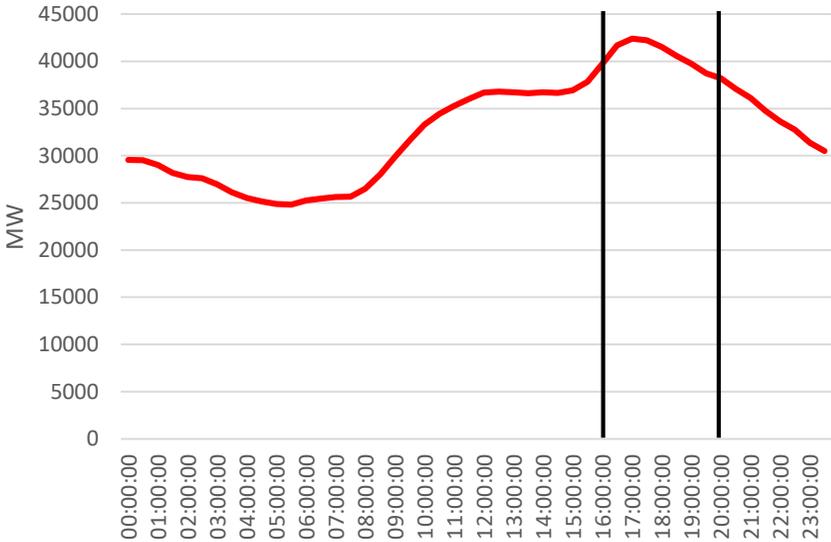
- Peaks
  - What they are
  - The peak problem
  - Understanding peaks
  
- Flexibility
  - Individuals
  - Activities
  - Winners and losers



# When I tell people I do research on peak electricity demand...



# ...but it is about this:



# THE PEAK PROBLEM





# The peak problem

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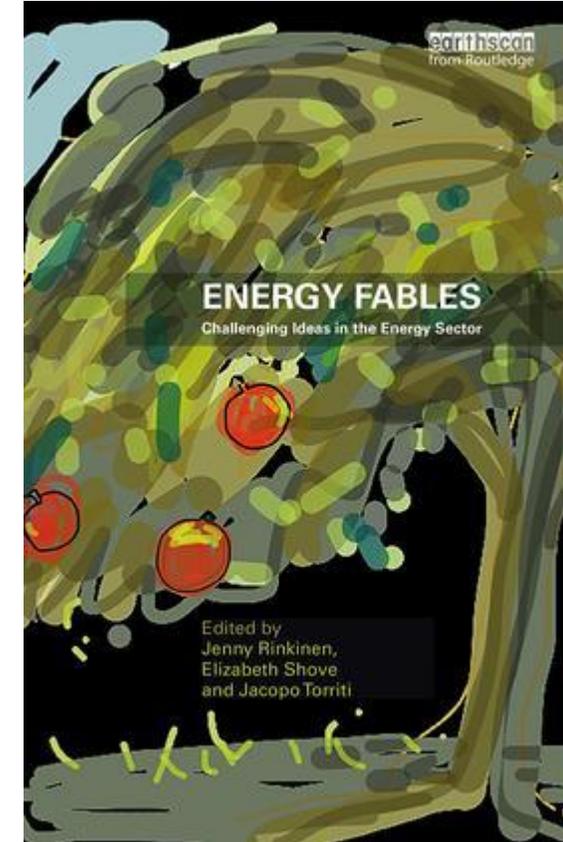
WINTER BLACKOUT FEAR: UK at risk as National Grid suffers 'multiple plant break downs'

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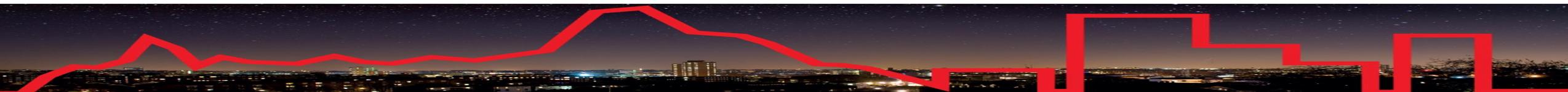
Blackout fears as factories are paid NOT to use electricity in 'last reason' bid to keep lights on across UK

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Winter blackout fear as power chiefs are forced to use emergency back-up

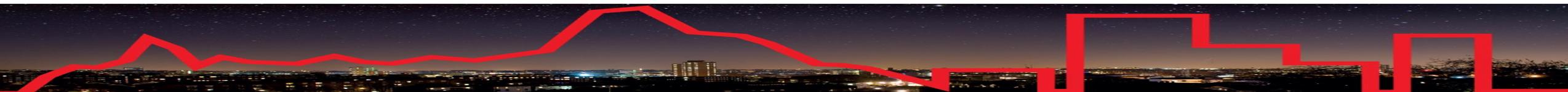


<https://www.routledge.com/Energy-Fables-Challenging-Ideas-in-the-Energy-Sector-1st-Edition/Rinkinen-Shove-Torriti/p/book/9780367027797>

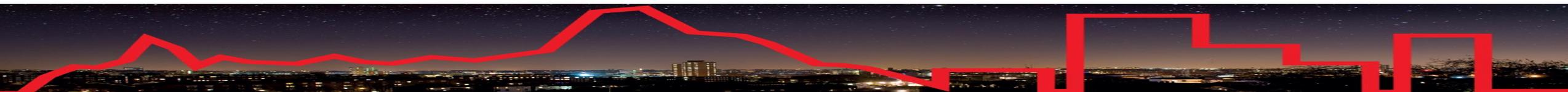


# The peak problem

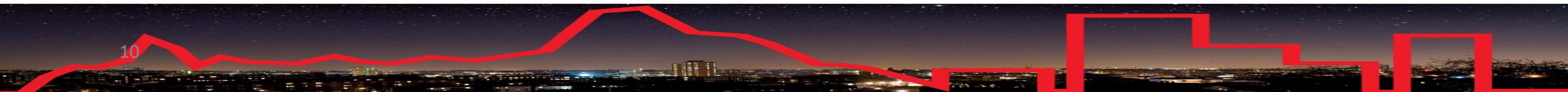
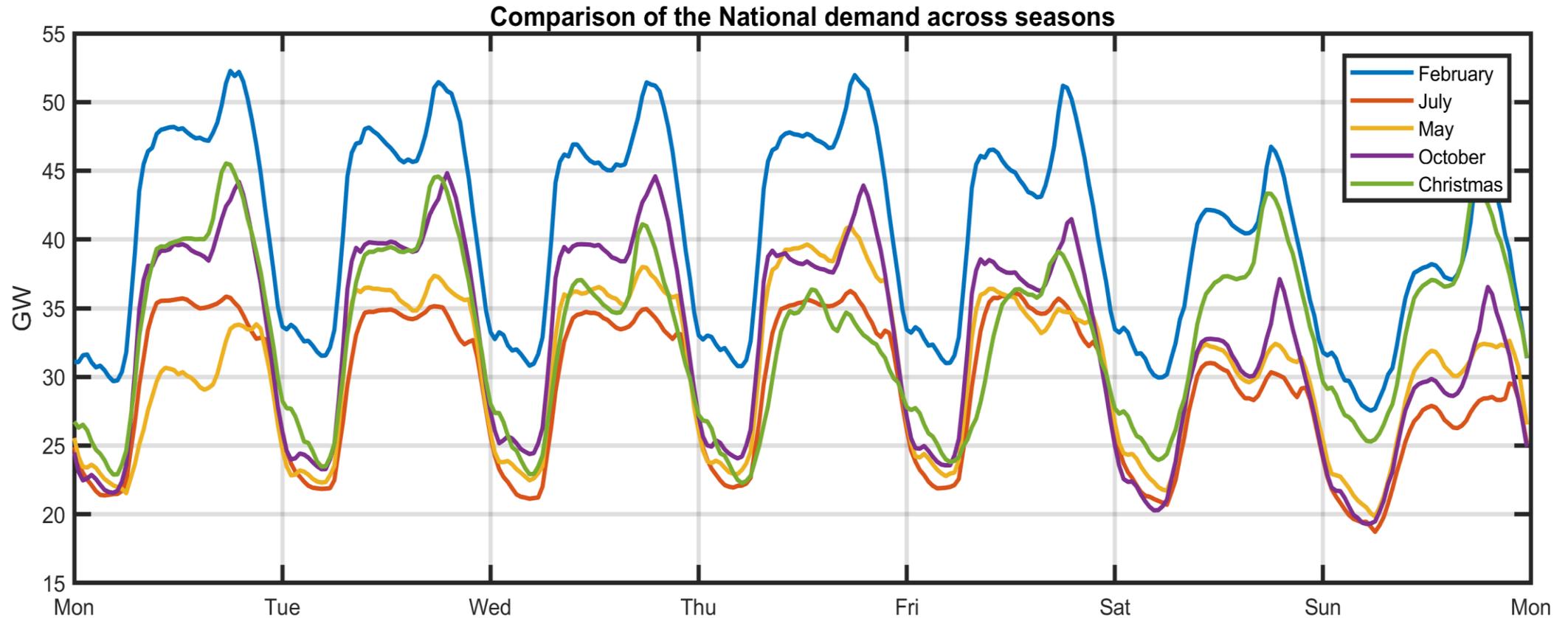
- Peaks in electricity demand bring about significantly negative environmental and economic impacts
- In the future:
  - intermittent renewables in the supply mix
  - electric vehicles and electric heat pumps



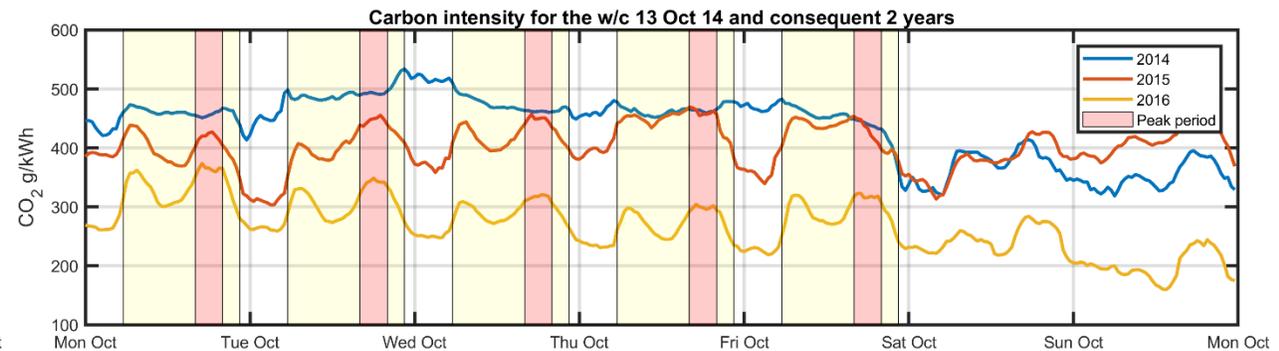
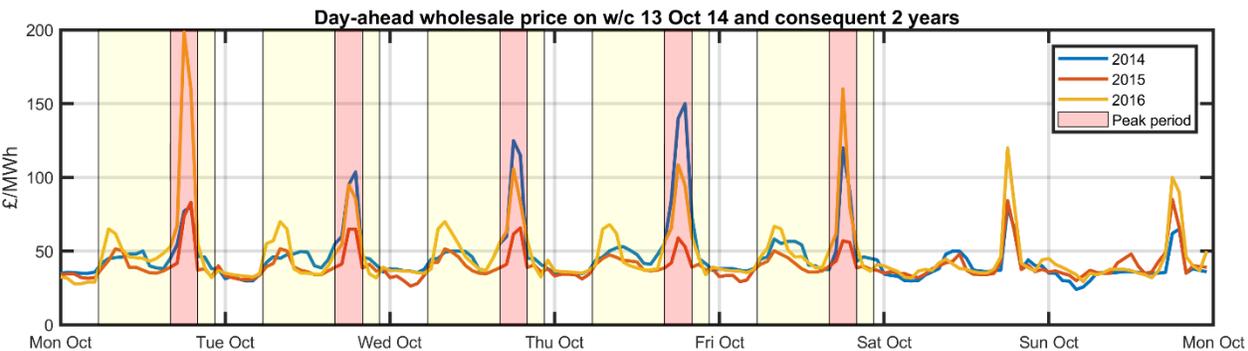
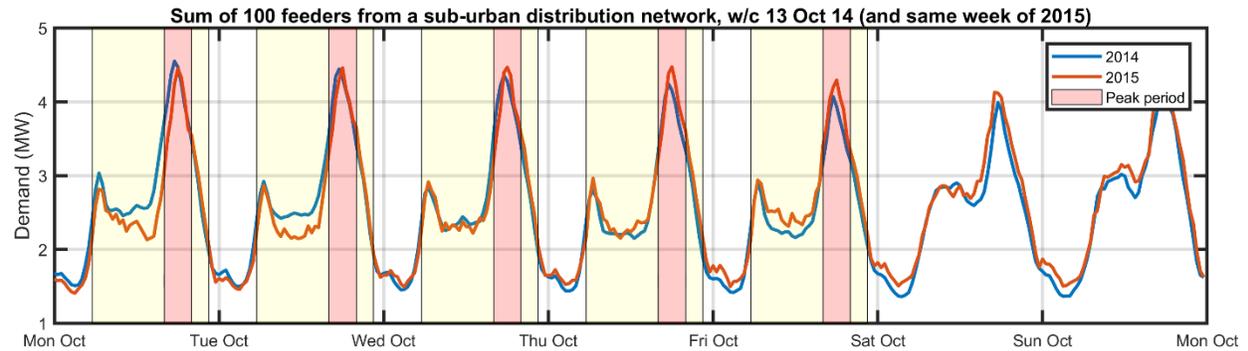
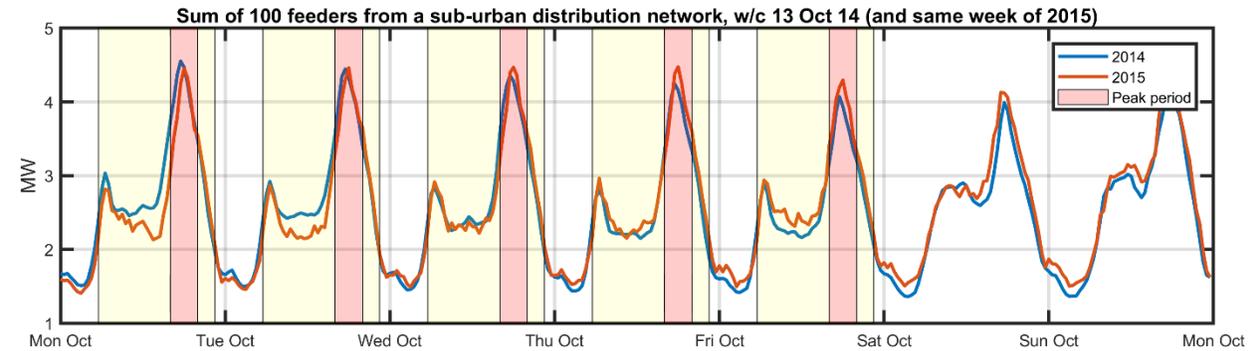
# UNDERSTANDING PEAKS



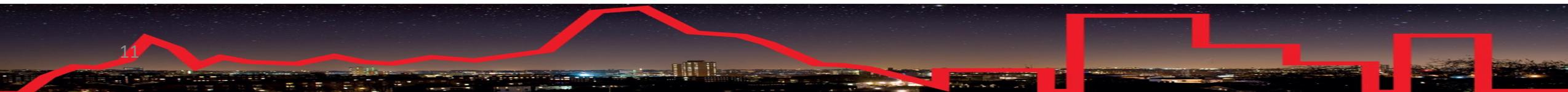
# Peaks every day



# Peaks: price and carbon intensity

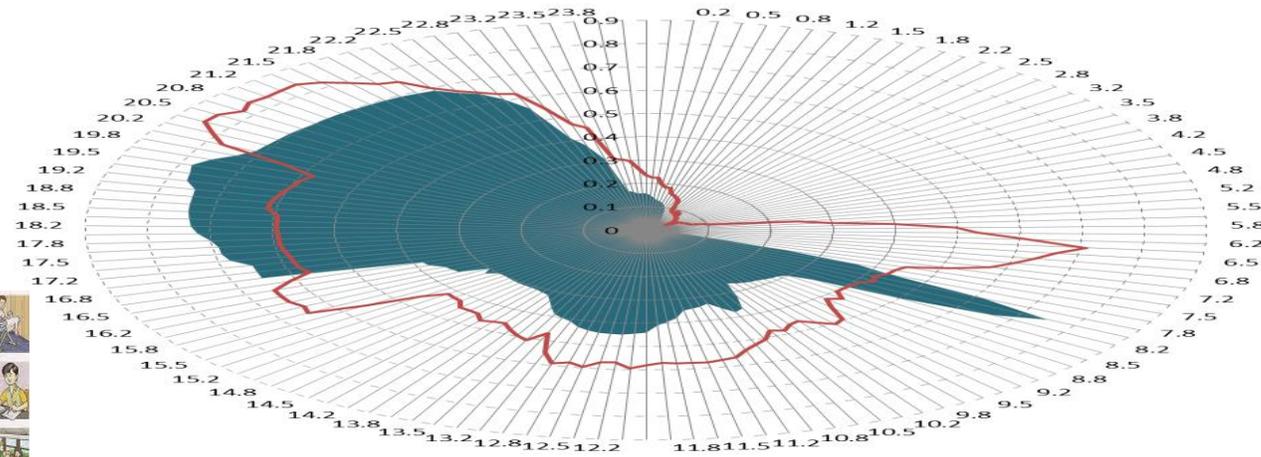


Source for Carbon intensity:



- Weekday

- Weekend

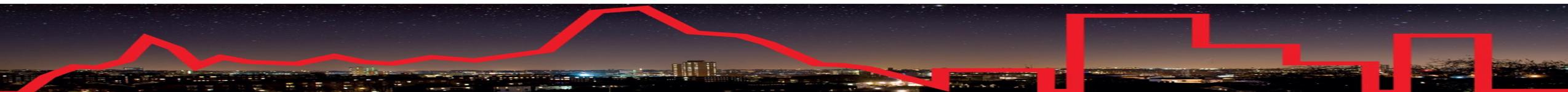


# Data on what people do



| Diary/<br>person<br>id | Starting<br>Time | Ending<br>Time | Main activity | Parallel activity | Who with: |        |                |                | Where/mode<br>of transport |
|------------------------|------------------|----------------|---------------|-------------------|-----------|--------|----------------|----------------|----------------------------|
|                        |                  |                |               |                   | Alone     | Spouse | Small<br>child | Other<br>pers. |                            |
| AA23                   | 04:00            | 07:20          | Sleep         |                   |           |        |                |                | At home                    |
| AA23                   | 07:20            | 07:50          | Shower        |                   |           |        |                |                | At home                    |
| AA23                   | 7:50             | 08:30          | Had breakfast | Read newspaper    |           |        | Ch             |                | At home                    |
| AA23                   | 08:30            | 08:40          | Walked to bus |                   | A         |        |                |                | By foot                    |
| AA23                   | 08:40            | 09:00          | Bus to job    |                   |           |        |                | OP             | By bus                     |

| Country | StartTime | Work and<br>study | Travel to/from<br>work/study | Household work | Sleep and<br>other<br>personal care | Eating | Freetime | TV and<br>video | Unspecified time |
|---------|-----------|-------------------|------------------------------|----------------|-------------------------------------|--------|----------|-----------------|------------------|
| Belgium | 04:00     | 1.04              | 0.07                         | 0.16           | 97.16                               | 0.15   | 1.01     | 0.17            | 0.24             |
| Belgium | 04:10     | 1.09              | 0.09                         | 0.28           | 97.14                               | 0.18   | 0.85     | 0.14            | 0.23             |
| Belgium | 04:20     | 1.09              | 0.15                         | 0.18           | 96.94                               | 0.4    | 0.81     | 0.17            | 0.25             |
| Belgium | 04:30     | 1.13              | 0.35                         | 0.23           | 96.51                               | 0.27   | 1.09     | 0.17            | 0.27             |
| Belgium | 04:40     | 1.23              | 0.34                         | 0.36           | 96.46                               | 0.2    | 0.97     | 0.15            | 0.29             |
| Belgium | 04:50     | 1.26              | 0.35                         | 0.44           | 95.81                               | 0.49   | 1.16     | 0.18            | 0.31             |
| Belgium | 05:00     | 1.53              | 0.34                         | 0.61           | 94.76                               | 0.49   | 1.78     | 0.21            | 0.27             |
| Belgium | 05:10     | 1.6               | 0.47                         | 0.68           | 94.82                               | 0.61   | 1.34     | 0.21            | 0.27             |
| Belgium | 05:20     | 1.71              | 0.64                         | 0.61           | 94.54                               | 0.65   | 1.25     | 0.24            | 0.36             |
| Belgium | 05:30     | 1.83              | 0.95                         | 0.7            | 93.31                               | 0.77   | 1.84     | 0.22            | 0.37             |
| Belgium | 05:40     | 1.94              | 1.26                         | 0.99           | 92.77                               | 0.74   | 1.74     | 0.24            | 0.3              |
| Belgium | 05:50     | 2.31              | 1.22                         | 1.08           | 91.76                               | 0.98   | 2.09     | 0.21            | 0.36             |
| Belgium | 06:00     | 3.08              | 1.06                         | 1.39           | 88.08                               | 1      | 4.81     | 0.23            | 0.34             |

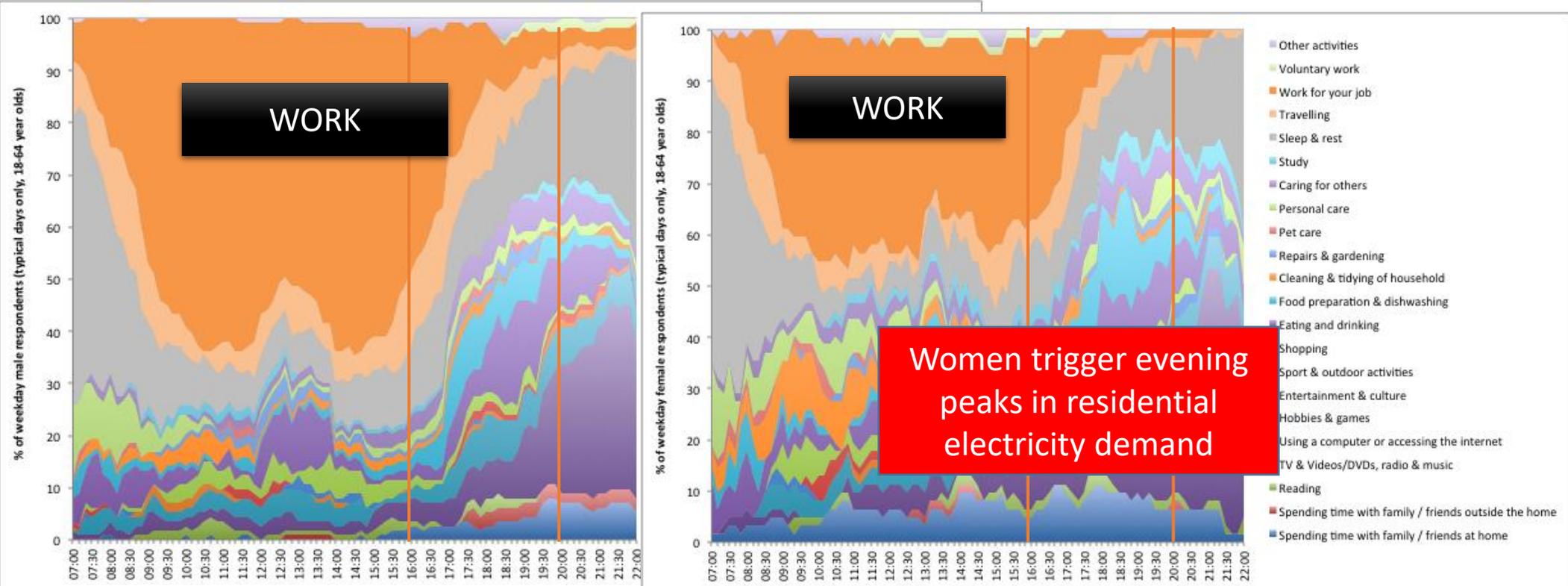


# Peaks and gender

Men



Women

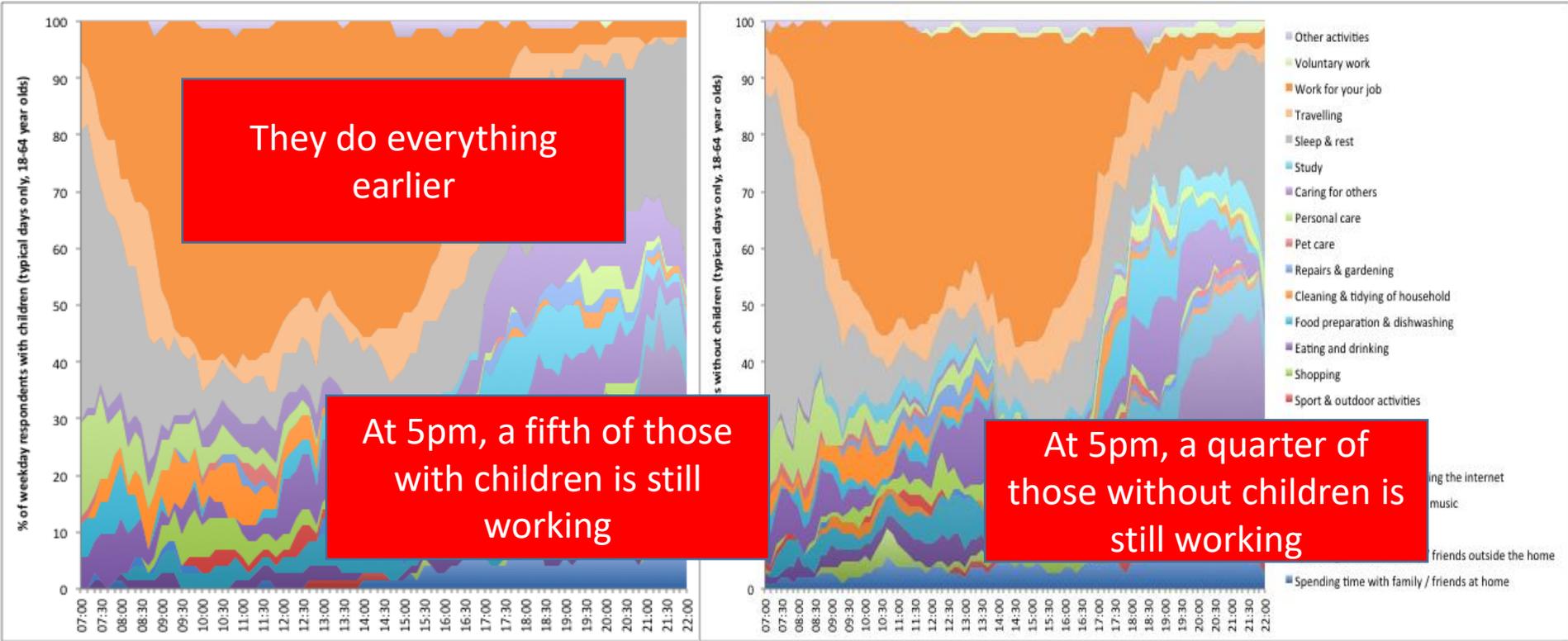


# Peaks and children

With Children  
children

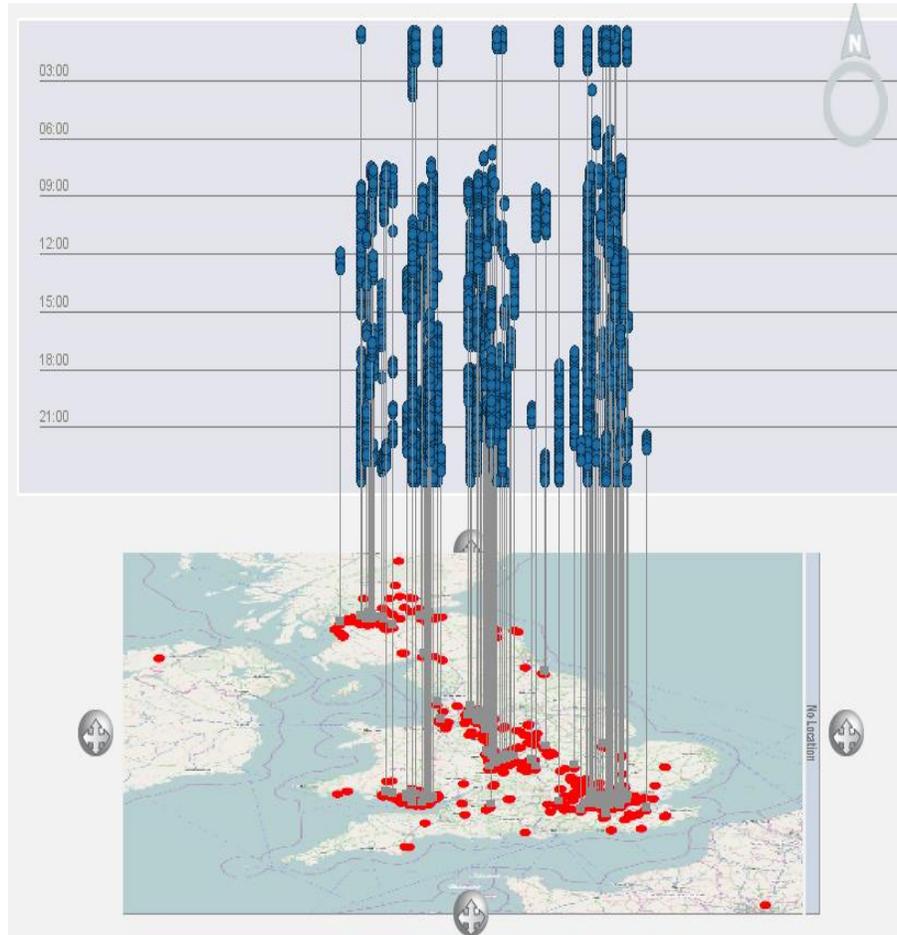


Without



# Knowing WHEN and WHERE

Computer use-UK



TV use-Spain



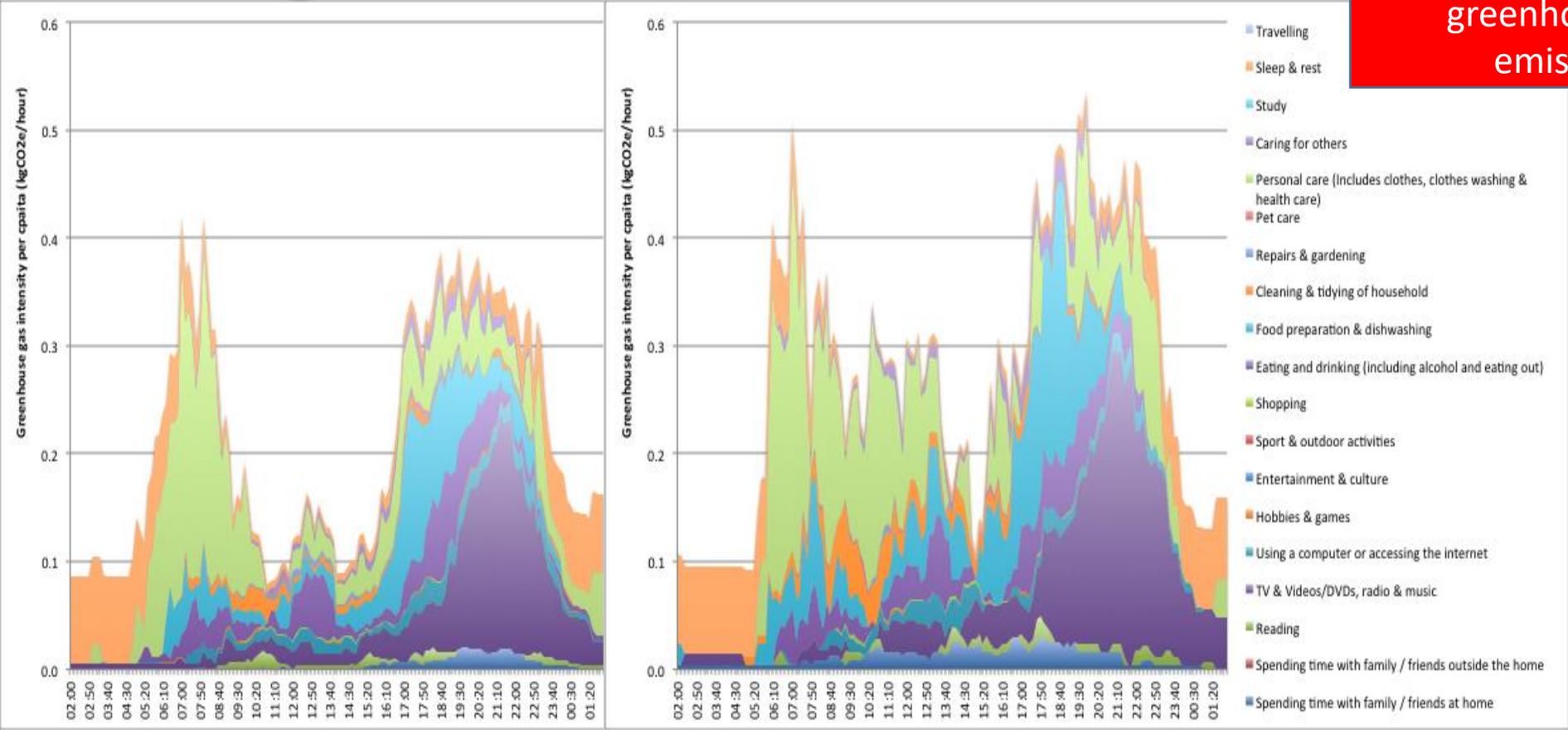
Average TV electricity consumption in Spain (MWh)

|                 |         | Morning Peak | Evening Peak |
|-----------------|---------|--------------|--------------|
| <b>Weekdays</b> | Minimum | 7,93         | 82,35        |
|                 | Maximum | 17,45        | 181,18       |
| <b>Weekends</b> | Minimum | 17,30        | 104,13       |
|                 | Maximum | 38,06        | 229,08       |

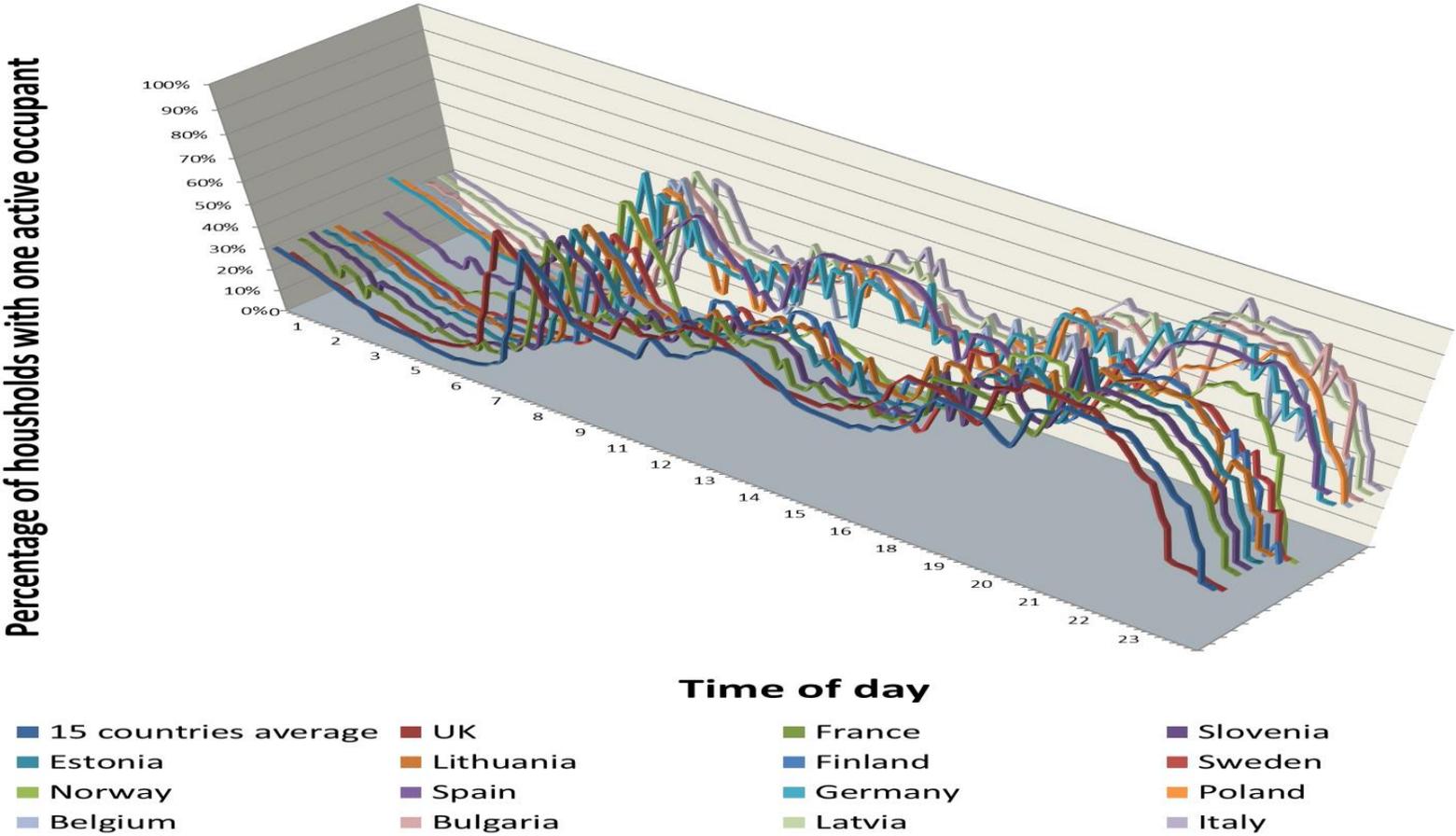
# Peaks and greenhouse gas emissions



Higher home occupancy reflects higher greenhouse gas emissions

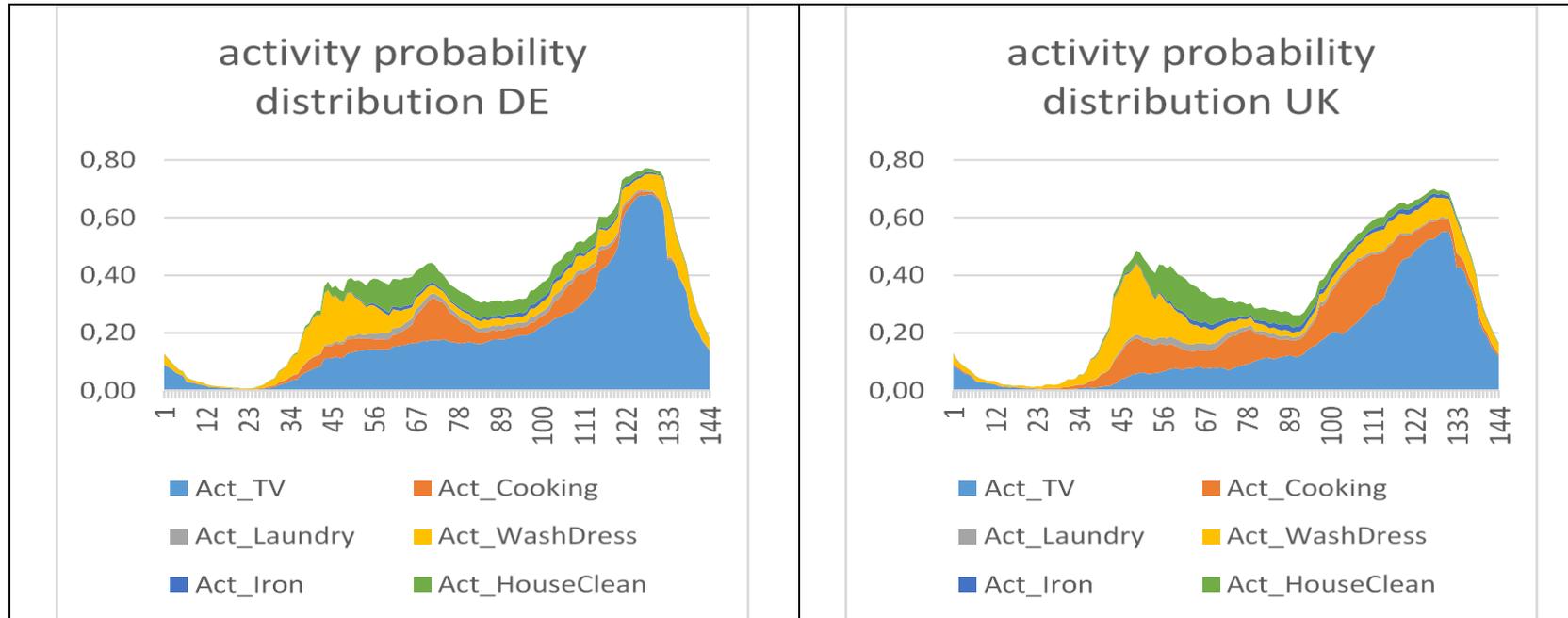


# Peaks and occupancy in different countries



# Peaks in Germany and the UK

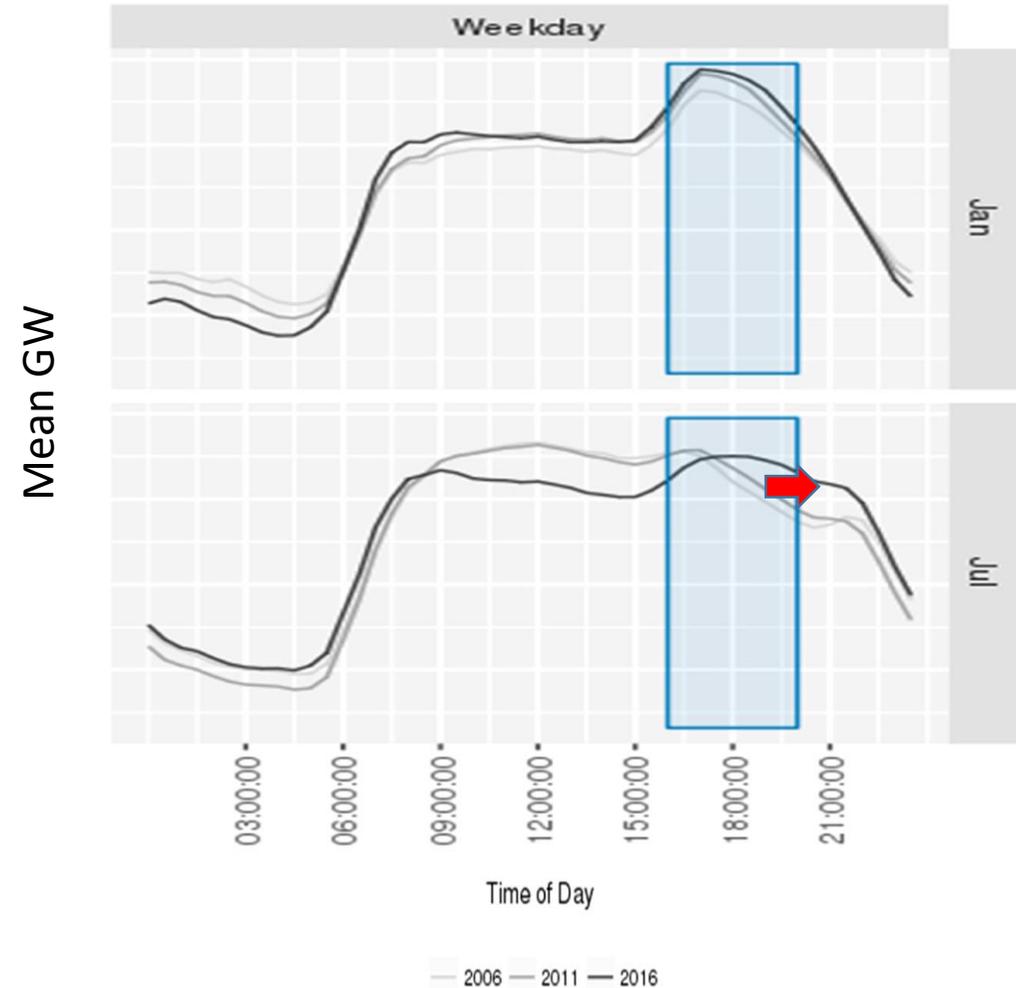
- Probability of  $\geq 1$  active person undertaking one of these six activities



- Stronger midday peak in DE, morning peak more pronounced in UK
- Higher evening peak in DE, compared to flatter/broader one in UK
- Strong similarities in evening TV watching habits

# Peaks across decades

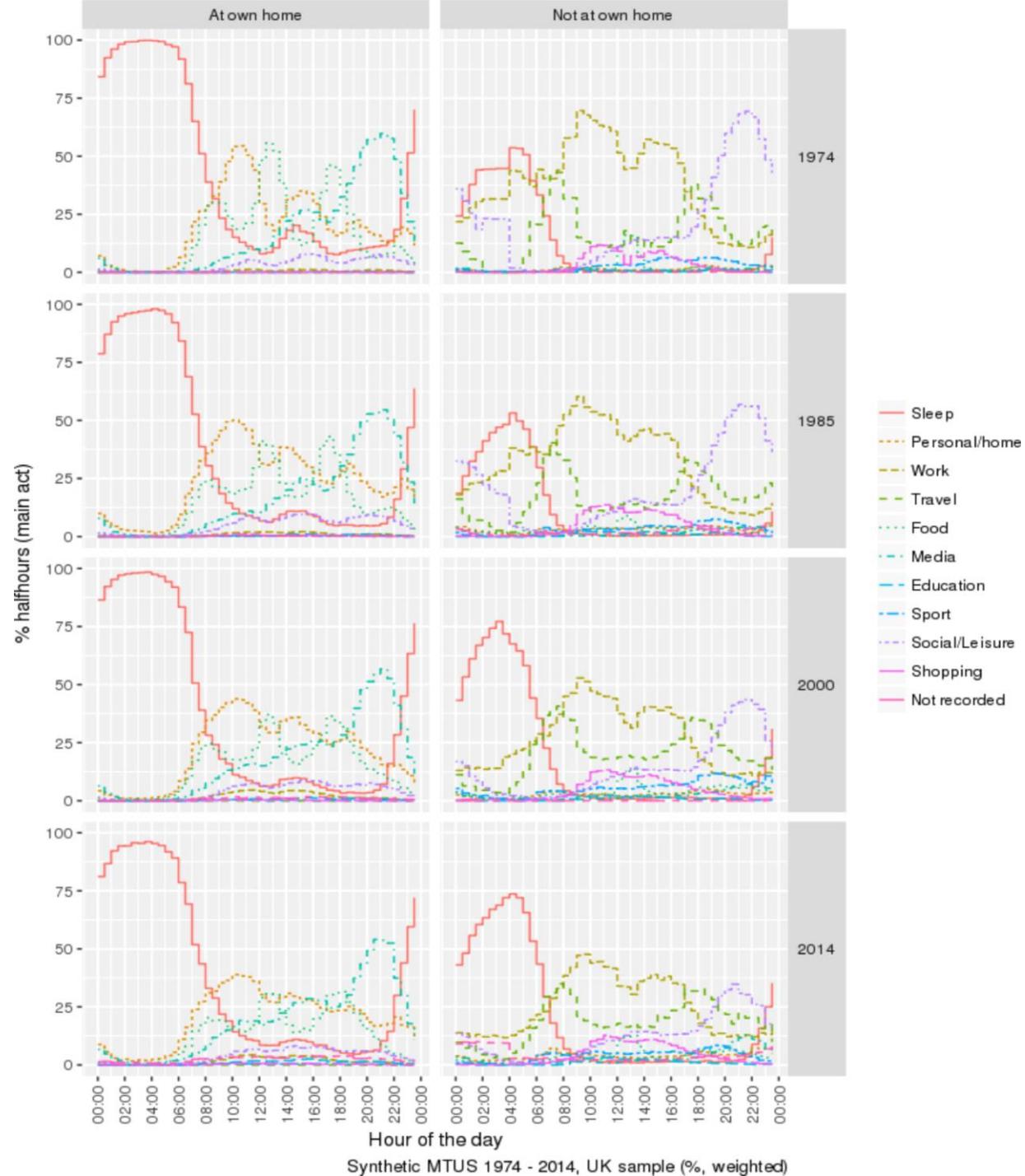
- Relative decrease in mid-day demand
- Evening peak is later
- This is especially visible in July



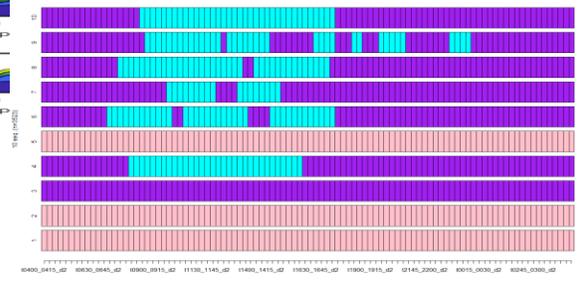
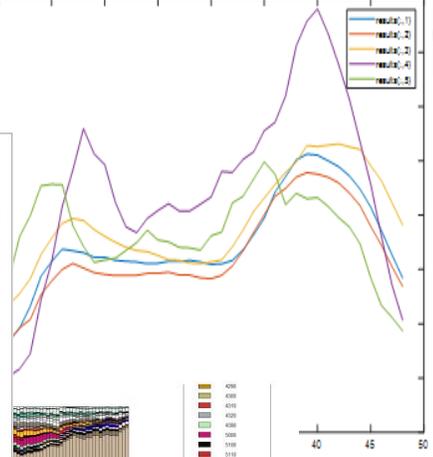
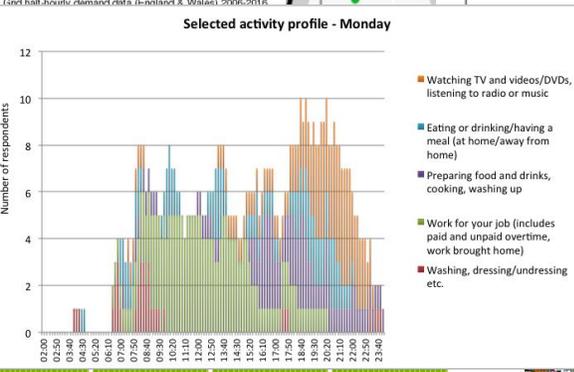
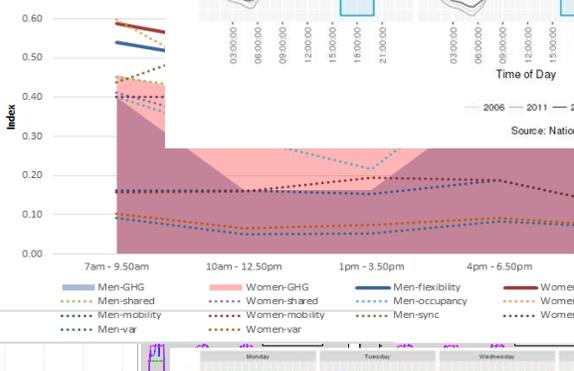
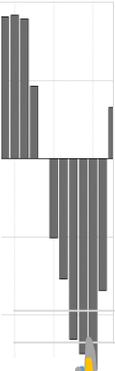
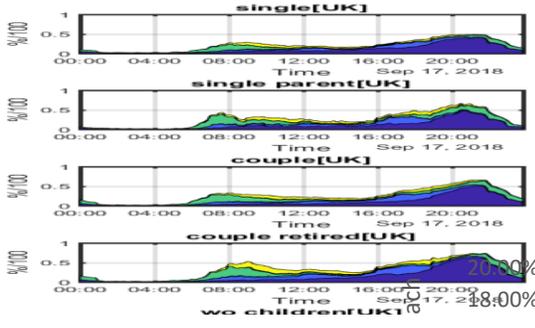
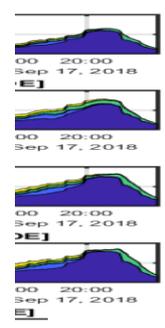
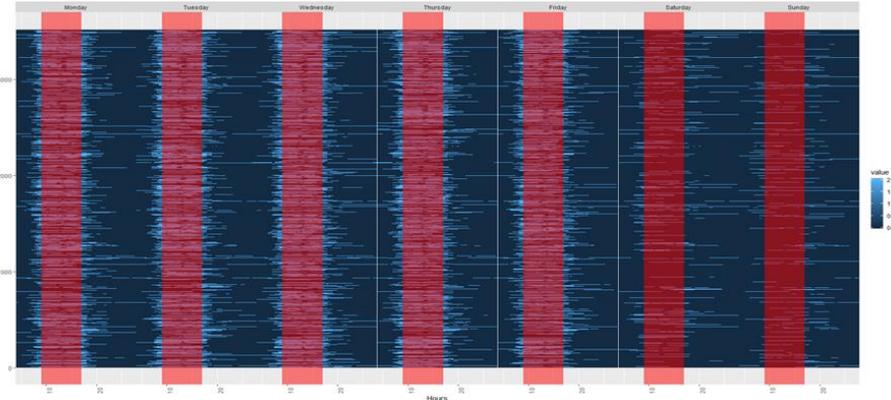
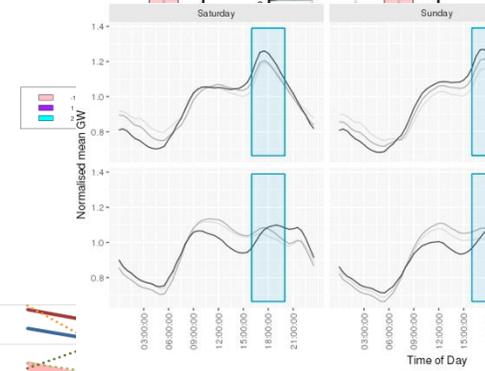
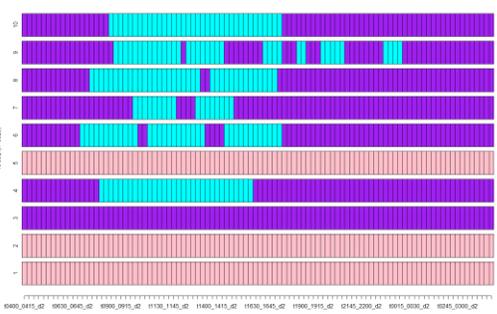
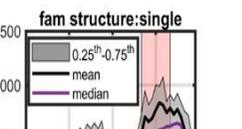
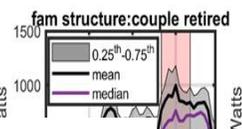
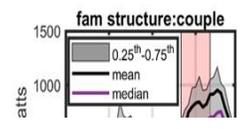
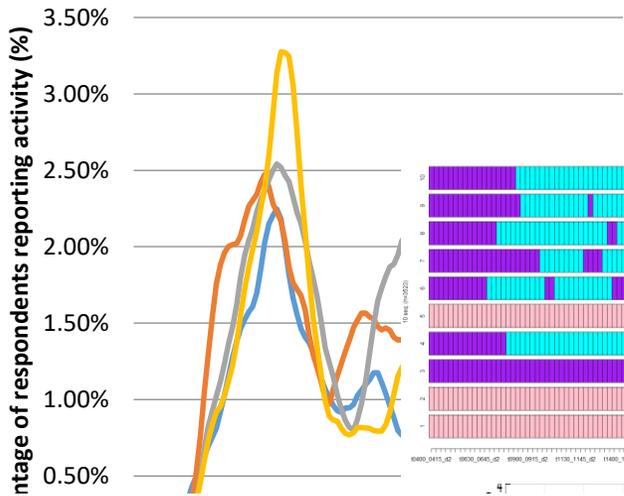
Source: National Grid half-hourly demand data (England & Wales) 2006-2016  
Peak demand period shown shaded



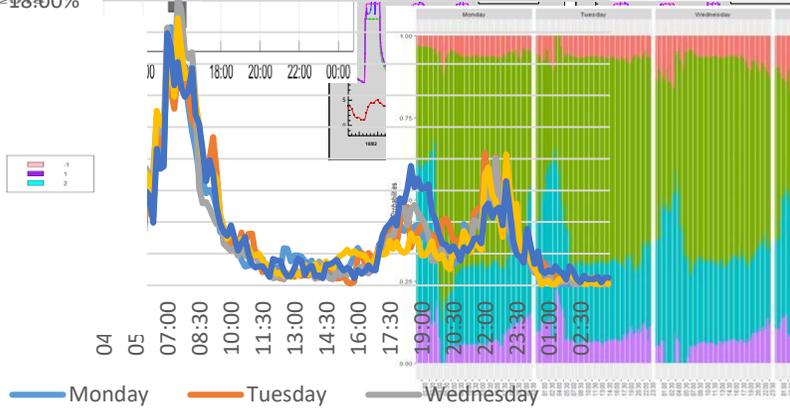
# Activities across decades



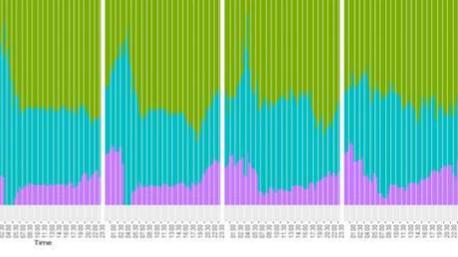
- Shift to later eating for all (especially working age)
- Reduced or shifted evening media use (squeezed between later eating and sleep)
- Reduction in morning weekday and Saturday 'personal/home care'
- Household care tasks have been shifted from weekdays to the evening peak period



Peri



Monday Tuesday Wednesday Thursday Friday



Work schedules

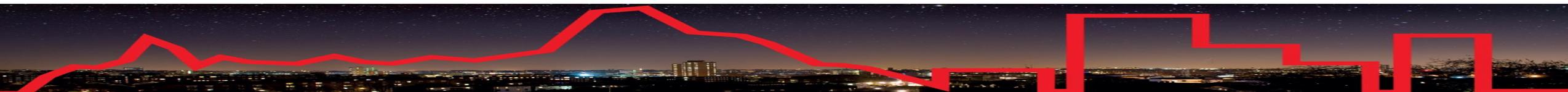




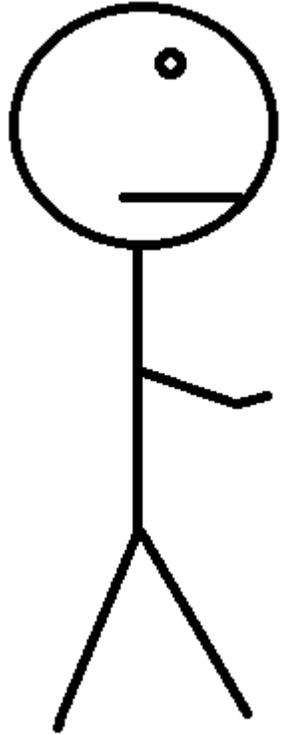
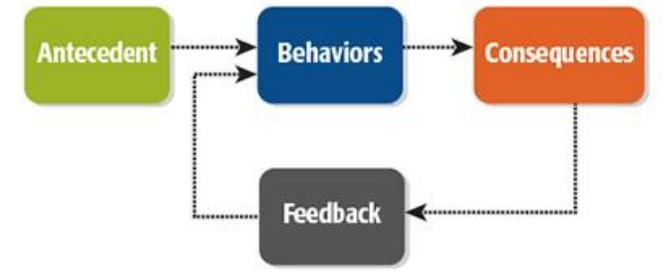
...AND THINK



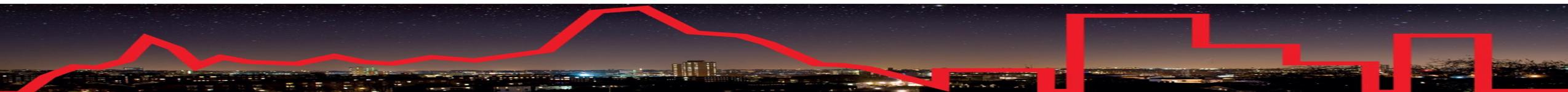
- What is energy demand for?
- Which concepts help explain the dynamics of energy demand?
- Why is there societal synchronisations?
- How can peaks be mitigated with non-energy arrangements?



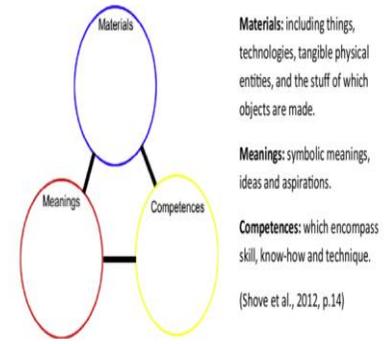
# Individual behaviour



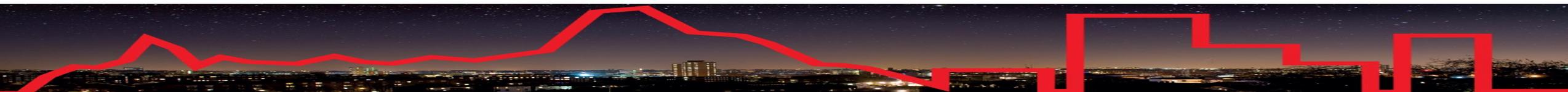
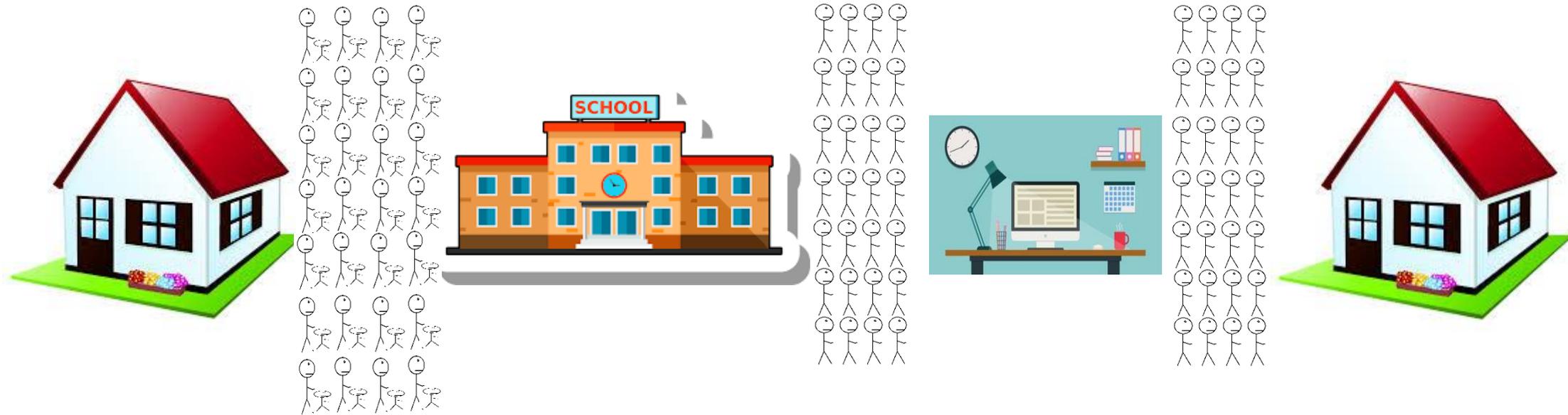
KWh € CO2



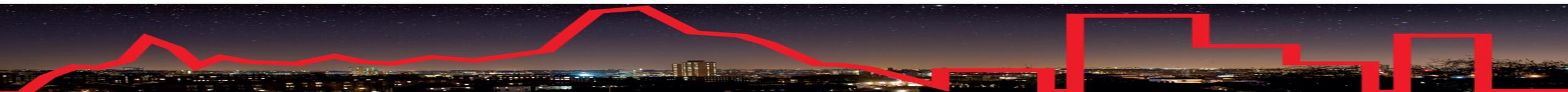
# Social practices



Shove, E., Pantzar, M., & Watson, M. (2012). *The dynamics of social practice: Everyday life and how it changes*. Sage.

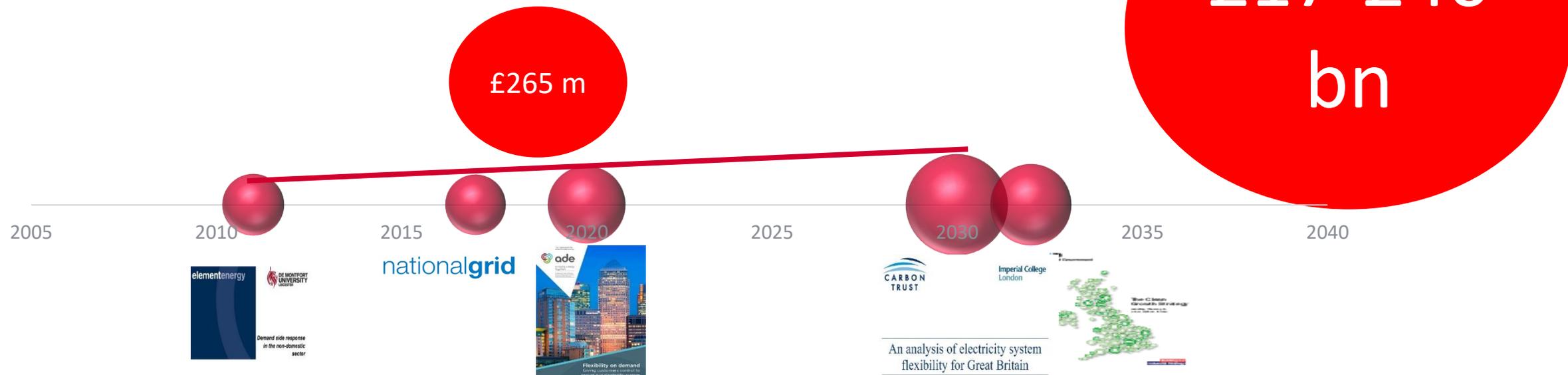


# FLEXIBILITY



# Flexibility: a win-win?

- Improving balancing with renewables
- Reducing costs of electricity generation
- Making the most of smart systems and battery storage

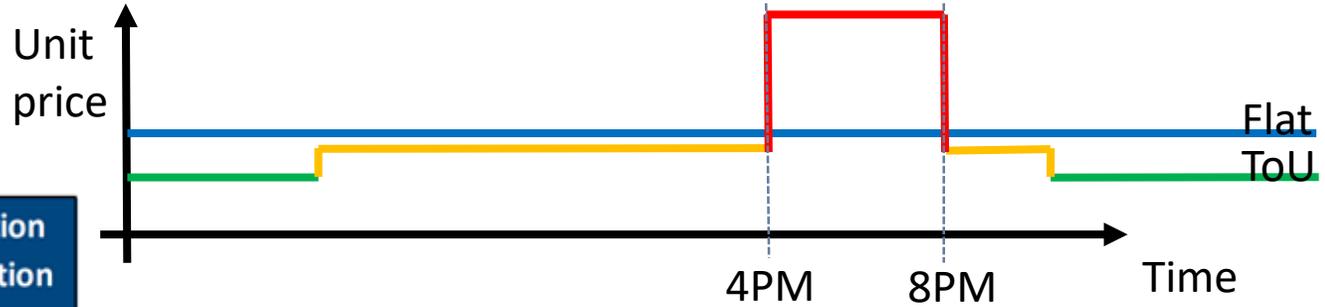




# Time of Use (ToU) tariffs

|                   | Current Trends | High Renewables | Electrification | Electrification w/Automation [1] |
|-------------------|----------------|-----------------|-----------------|----------------------------------|
| <b>Static TOU</b> |                |                 |                 |                                  |
| Opt-in            | 5%             | 5%              | 7%              | 8%                               |
| Opt-out           | 3%             | 3%              | 4%              | N/A                              |
| <b>iTOU</b>       |                |                 |                 |                                  |
| Opt-in            | N/A            | 10% [2]         | N/A             | N/A                              |

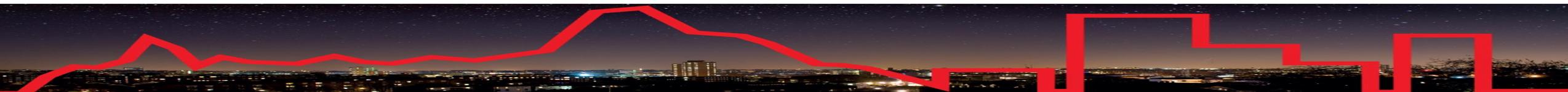
Source: Hledik et al (2017), "The Value of Time of Use Tariffs in Great Britain: Insights for Decision Makers: Final Report", Report prepared for Citizens Advice. July 2017.



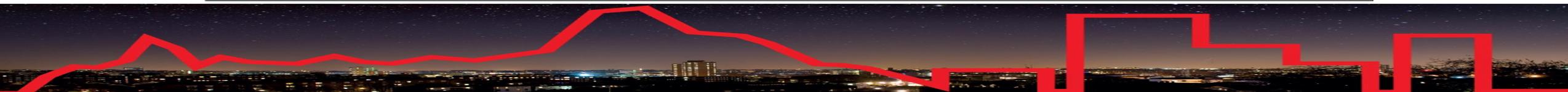
# APPROACH 1: Individual behaviour => price elasticity of demand



- Simple web-based choice experiment to elicit preferences for fixed tariffs and two dynamic tariffs (Time of Use and Critical Peak Pricing)
- The price attribute was framed as an electricity bill discount (i.e. a WTA format) to switch to the dynamic tariff
- Respondents were presented with four labelled choice cards
- Respondents were randomly divided into two sub-samples, with environmental and system benefits information presented to only one



| Tariff Type   | Fixed   | Time of Use (TOU)   | Critical Peak Pricing (CPP)   |
|---|---|---|---|
| Description   | *Price stays the same throughout the day.                     | * <b>Cost:</b> Rate is 50% higher than your current fixed rate 6 hours of the day, every weekday, from 2pm until 8pm, during daily high demand.<br>* <b>Benefit:</b> Rate is 25% lower than your current fixed rate all other times.  | * <b>Cost:</b> On 10 weekdays selected by the electric company prices will raise 8x from your current fixed rate for 6 hours, from 2pm to 8pm, during emergency conditions. Your electric company notifies you one day in advance.<br>* <b>Benefit:</b> Rate is 25% lower than your current fixed rate all other times that day and all other days in the year.   |
| Environmental and Grid Benefits   | *None   | *Less water and air pollution.<br>*Aid the expansion of renewable energy.<br>*Increased electricity reliability.<br>*Slow the rate of electricity price increases.  | *Less water and air pollution.<br>*Aid the expansion of renewable energy.<br>*Increased electricity reliability.<br>*Slow the rate of electricity price increases.  |
| Graphic   | <p>Fixed Rate (\$/kilowatt-hour)</p> <p>Flat Rate: \$0.10</p> | <p>Fixed vs. TOU (\$/kilowatt-hour)</p> <p>Flat Rate: \$0.075<br/>TOU - All Year: \$0.10, \$0.15</p>  | <p>Fixed vs. CPP (\$/kilowatt-hour)</p> <p>Flat Rate: \$0.075<br/>CPP - Peak Days: \$0.10, \$0.80</p>   |
| Required Behavior Change to get Savings   | *None - it's your current plan.                               | <b>Sustained, moderate changes during daily high priced times:</b><br>* <b>All regions:</b> Shift all listed appliances.<br>* <b>U.S.:</b> Adjust thermostat up by 2F (1C) from 75F (25C) during the summer.<br>* <b>Europe:</b> If you use electric heating, adjust your thermostat down by 2F (1C) from 68F (20C) during the winter. Use stand-alone electric room heaters at their lowest setting. | <b>Oneoff, significant changes during 10 days' high priced times:</b><br>* <b>All regions:</b> Shift all listed appliances.<br>* <b>U.S.:</b> Adjust thermostat up by 5F (2.5C) from 75F (25C) during the summer. Turn off window and room air conditioning units, and all but essential lighting.<br>* <b>Europe:</b> If you use electric heating, adjust your thermostat down by 5F (2.5C) from 68F (20C) during the winter. Turn off stand-alone electric room heaters. Turn off all but essential lighting. Restrict use of electric cooking appliances by 50%. |
| Potential Bill Increase with No Behavior Change   | 0%  | 0% to 5%<br>\$0 to \$5.00 per month   | 0% to 5%<br>\$0 to \$5.00 per month   |
| Potential Bill Savings with Behavior Change<br>Note: the last 2 columns in this row change with each selection. | 0%  | 10%<br>Approximately \$10.00 per month  | 5%<br>Approximately \$5.00 per month  |
| Please Select One   | Choice 1  | Choice 2  | Choice 3  |

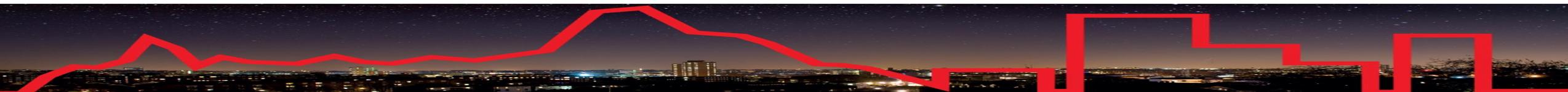


# Discount needed for shifting electricity demand

|                  | Coefficient | Std. Error | MWTA <sup>a</sup> | Std. Error <sup>b</sup> |
|------------------|-------------|------------|-------------------|-------------------------|
| DISCOUNT         | 0.163***    | 0.020      |                   |                         |
| TOU <sup>c</sup> | -1.993**    | 0.830      | 12.22%            | 4.91%                   |
| E&SxTOU          | 1.599***    | 0.622      | -9.81%            | 3.87%                   |
| MALExTOU         | -1.779***   | 0.627      | 10.91%            | 3.91%                   |
| HIBILLxTOU       | 1.255**     | 0.619      | -7.70%            | 3.82%                   |
| STUDENTxTOU      | -0.056      | 0.629      | 0.34%             | 3.86%                   |
| EASYxTOU         | 2.848***    | 0.657      | -17.47%           | 4.19%                   |
| CPP <sup>c</sup> | -3.009***   | 1.039      | 18.45%            | 6.20%                   |
| E&SxCPP          | 2.086***    | 0.788      | -12.80%           | 4.87%                   |
| MALExCPP         | -1.437*     | 0.790      | 8.81%             | 4.88%                   |
| HIBILLxCPP       | -0.390      | 0.793      | 2.39%             | 4.86%                   |
| STUDENTxCPP      | -1.728**    | 0.804      | 10.60%            | 4.97%                   |
| EASYxCPP         | 1.981**     | 0.802      | -12.15%           | 5.01%                   |

Standard Deviations of Random Coeffs.

|                |          |         |           |
|----------------|----------|---------|-----------|
| TOU            | 2.776*** | 0.381   |           |
| CPP            | 3.365*** | 0.535   |           |
| Df             |          |         | 13        |
| Replications   |          |         | 1000      |
| Observations   |          |         | 1920      |
| Log likelihood |          |         | -438.380  |
| LR $\chi^2$    |          | SDs (2) | 205.56*** |



# APPROACH 2: Activities as the unit of analysis

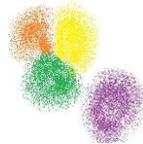


- Clustering based on what people do at peak time

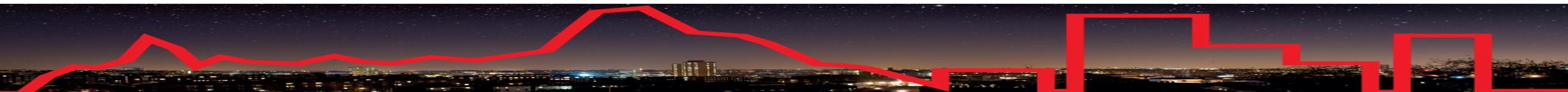


- Imposing Time of Use tariffs on different:

- Socio-demographic groups
- Clusters

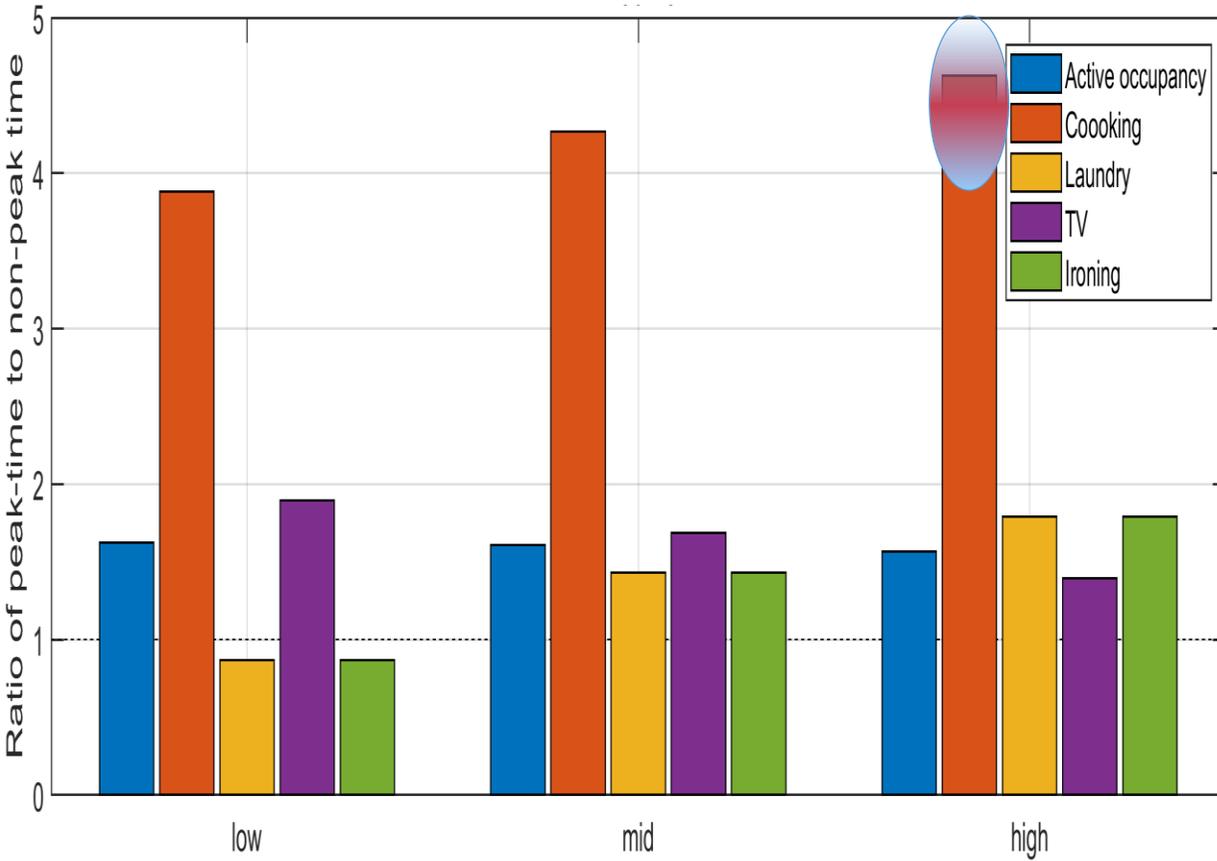


- Automation and everyday life

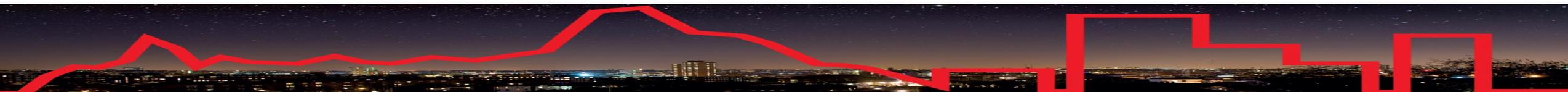
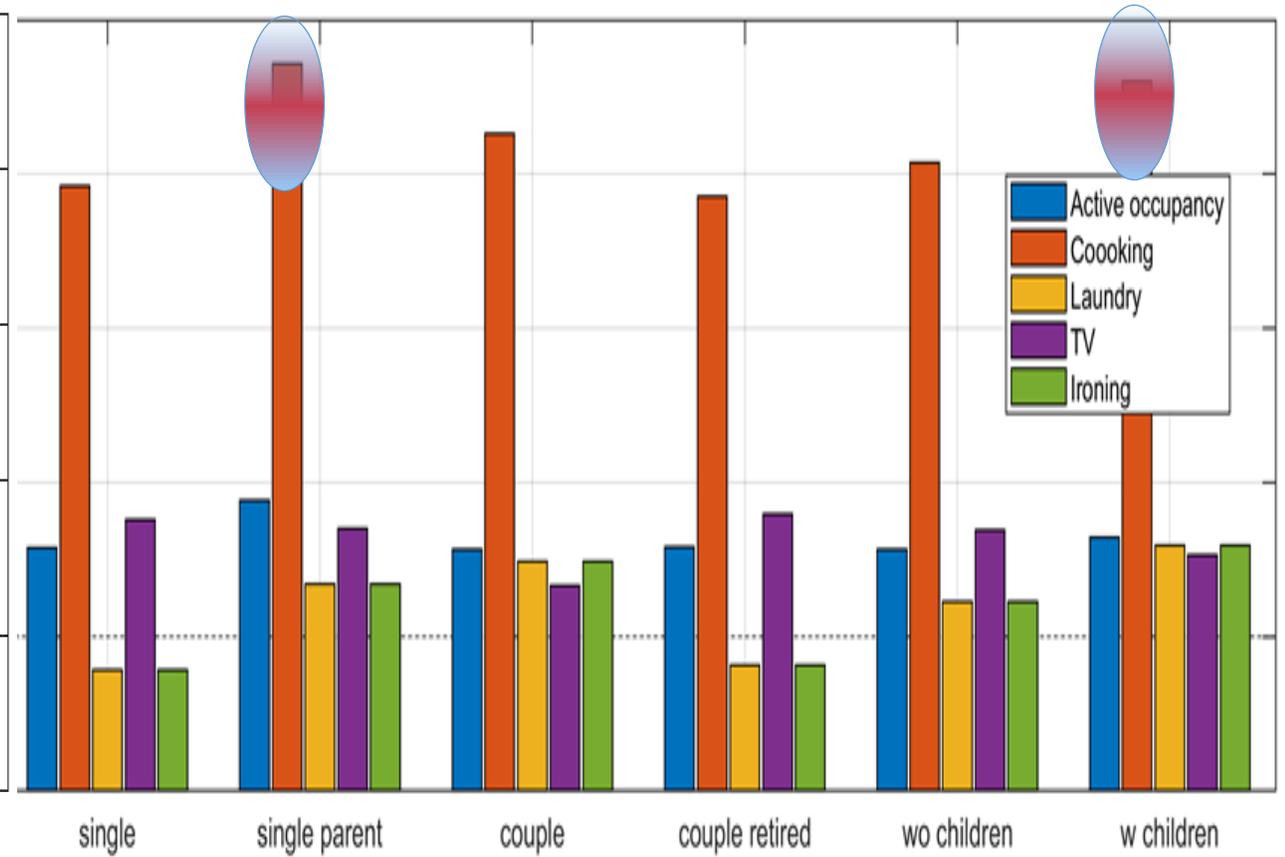




# Comparison peak and off-peak activities: income

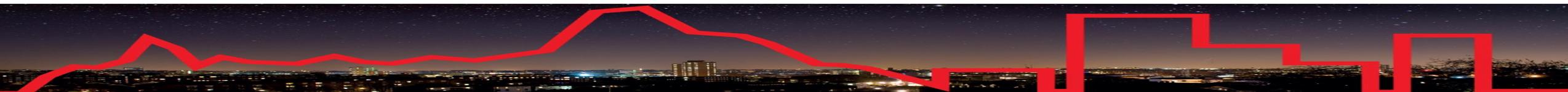
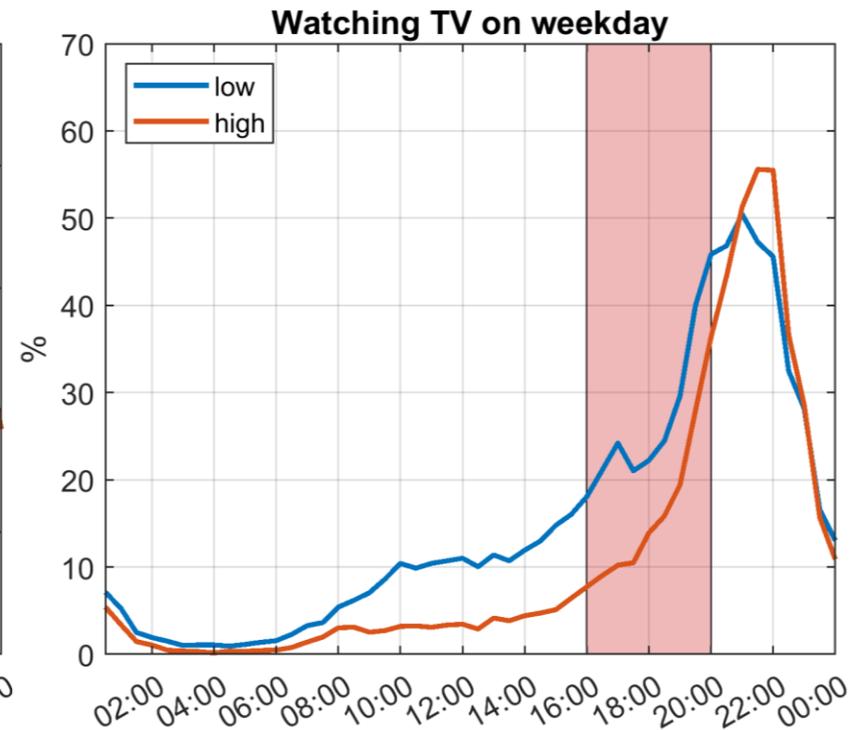
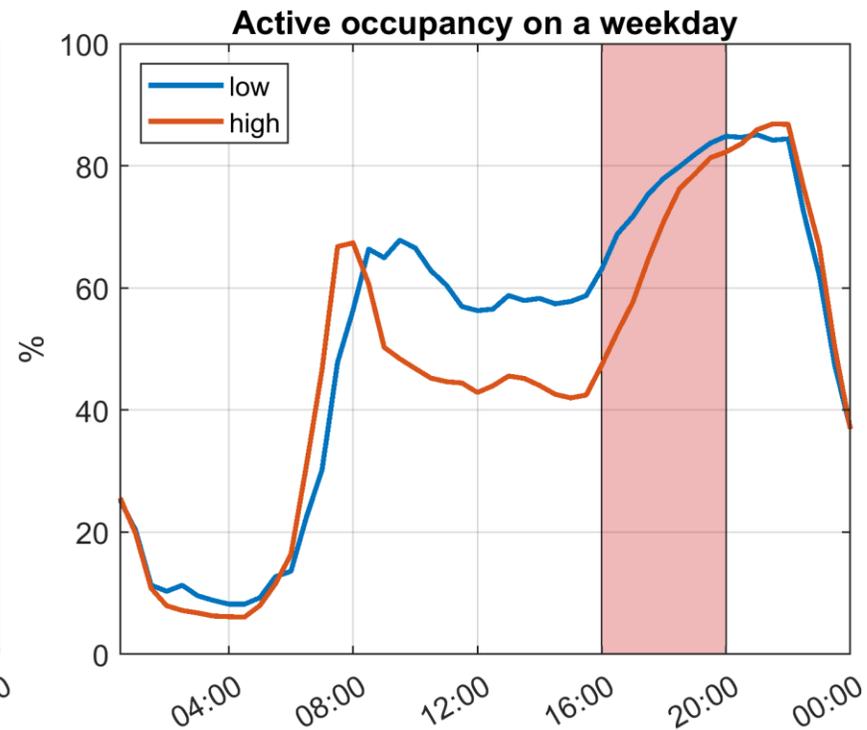
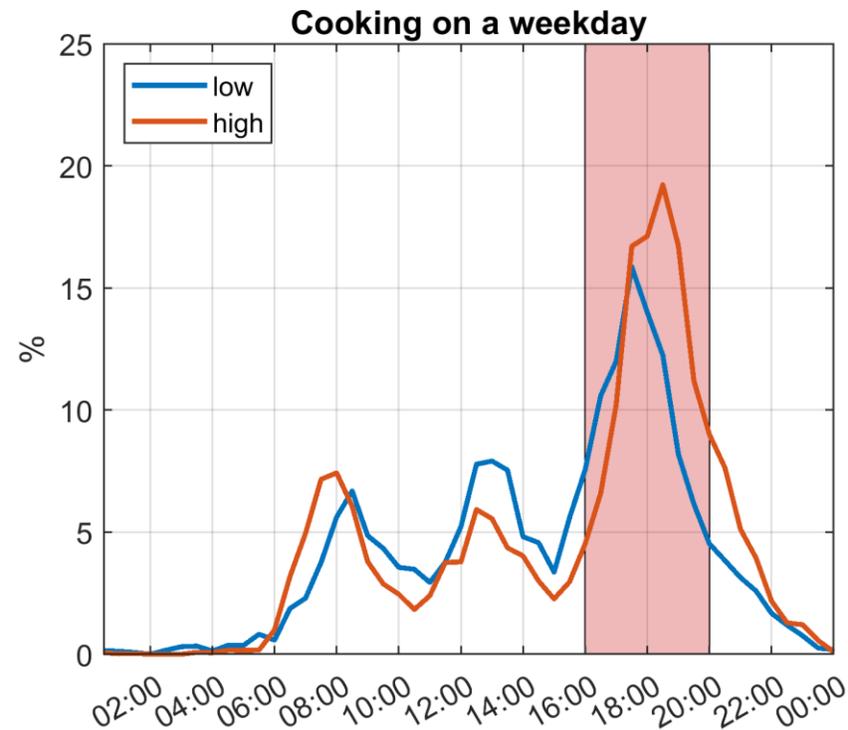


# Comparison peak and off-peak activities: household composition



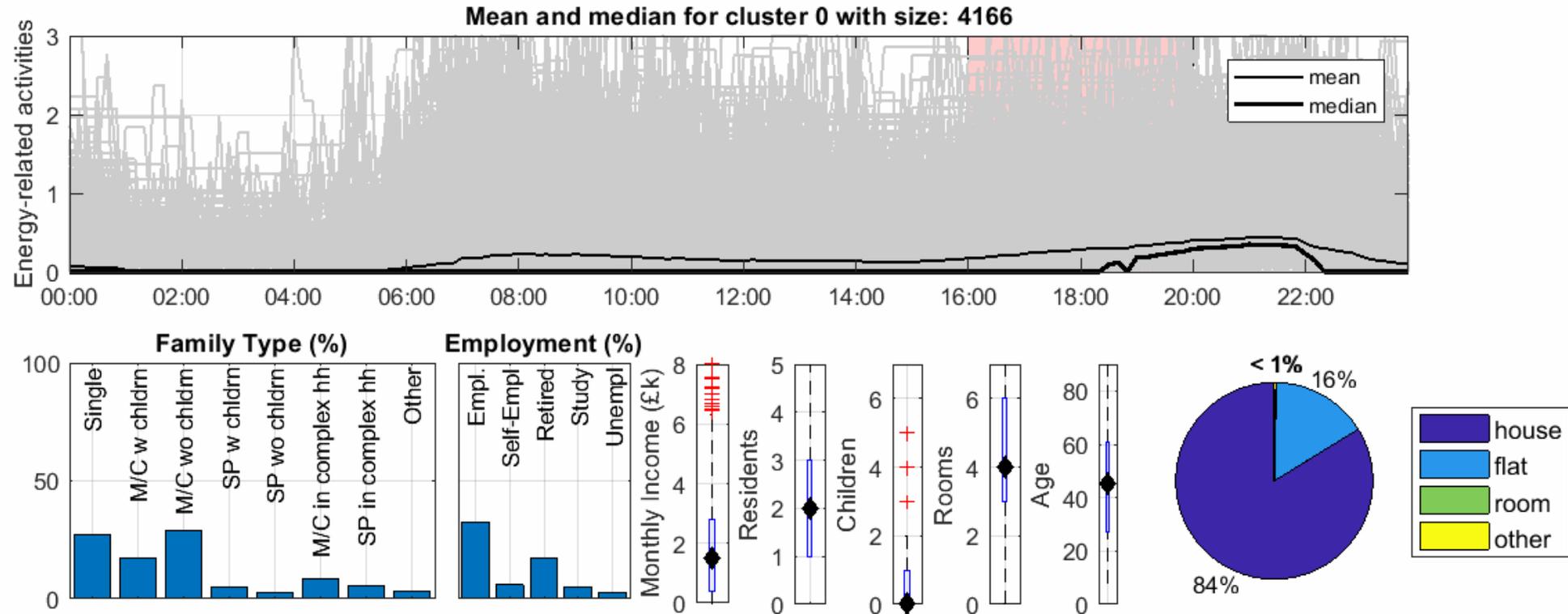


# Peak to off-peak ratio: Income





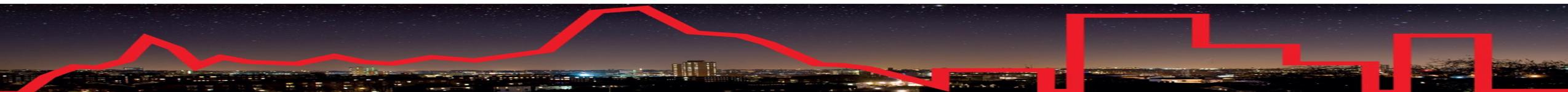
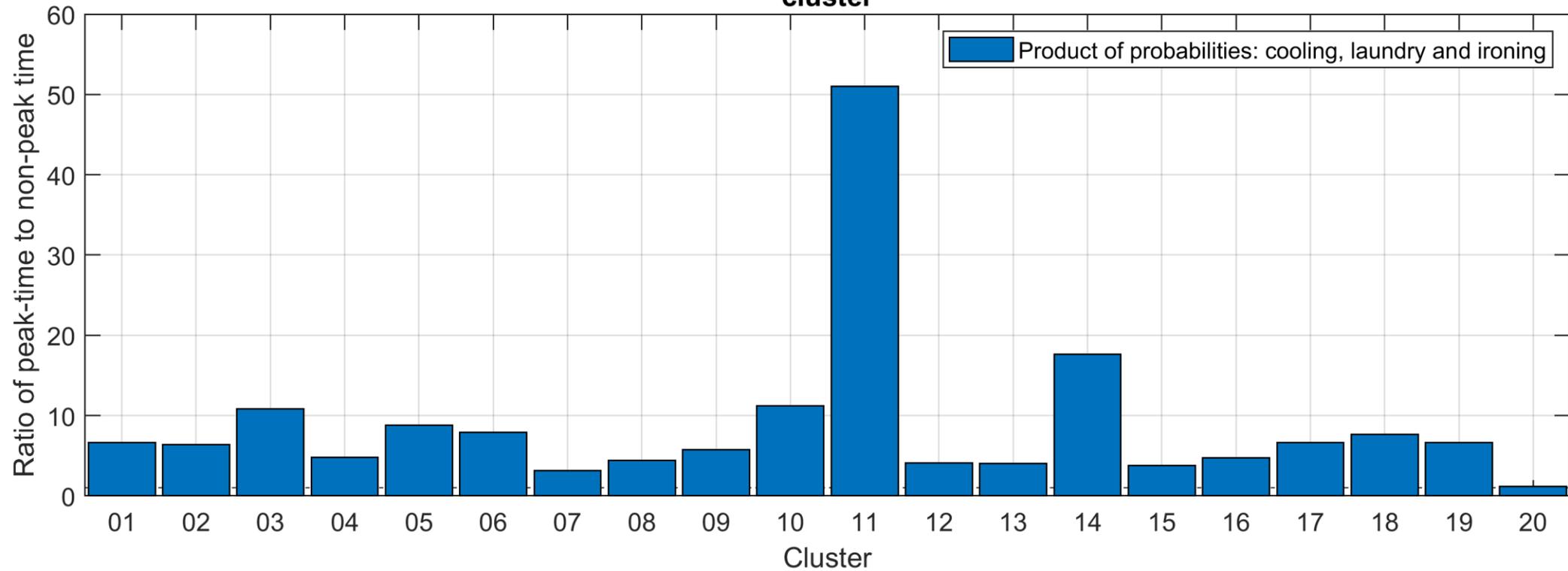
# Clustering households by activity



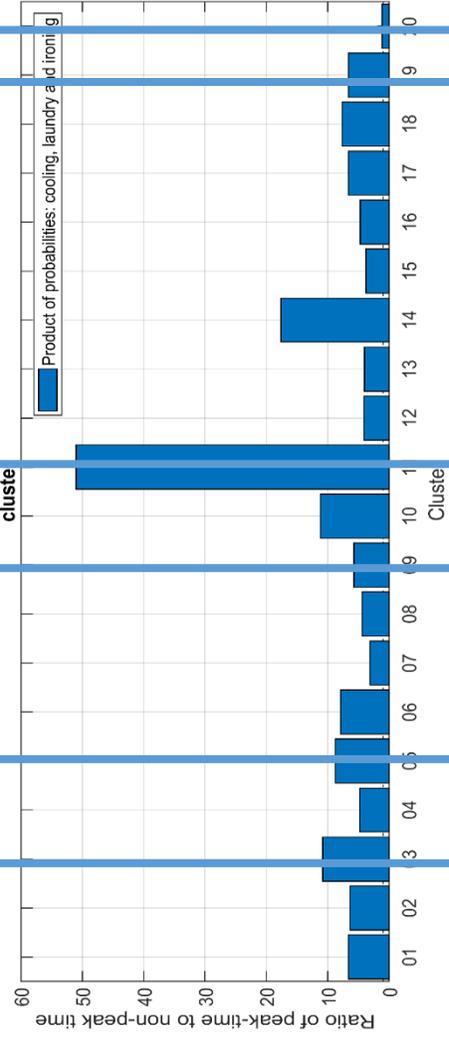


# Peak to off-peak ratio

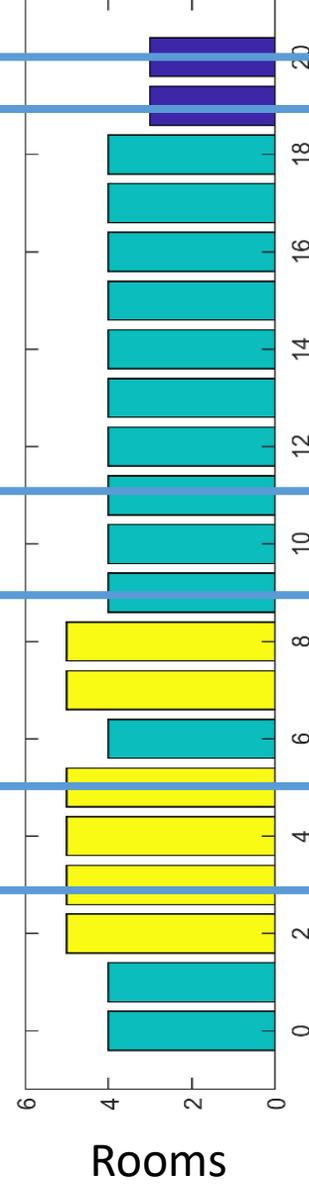
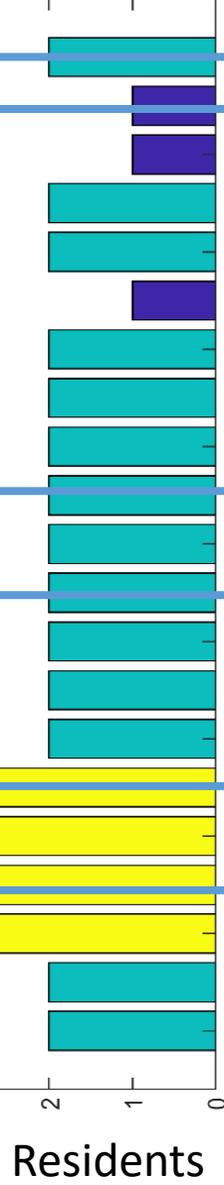
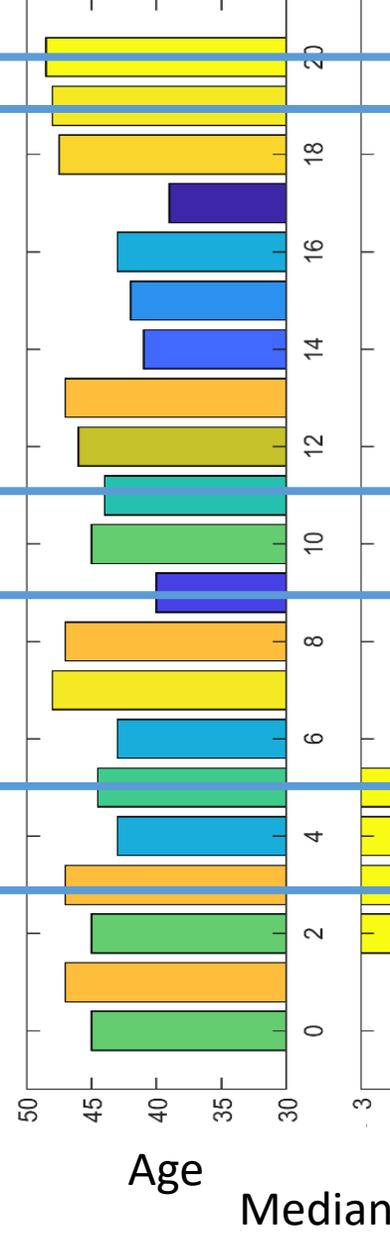
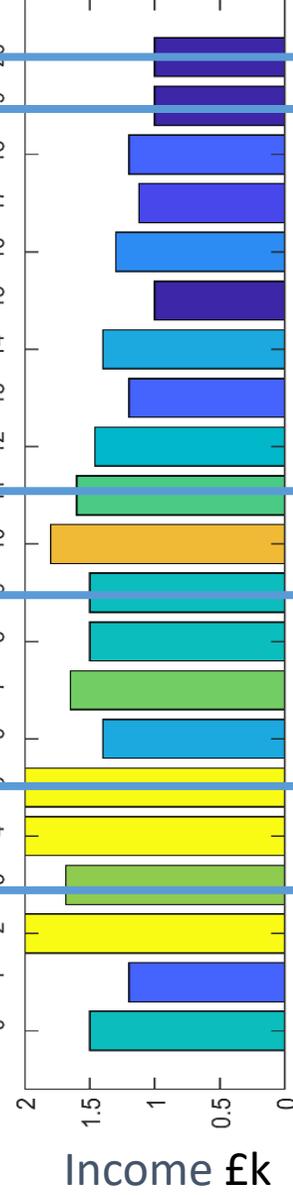
Comparison of peak-time and non-peak time activities for parameter:  
cluster



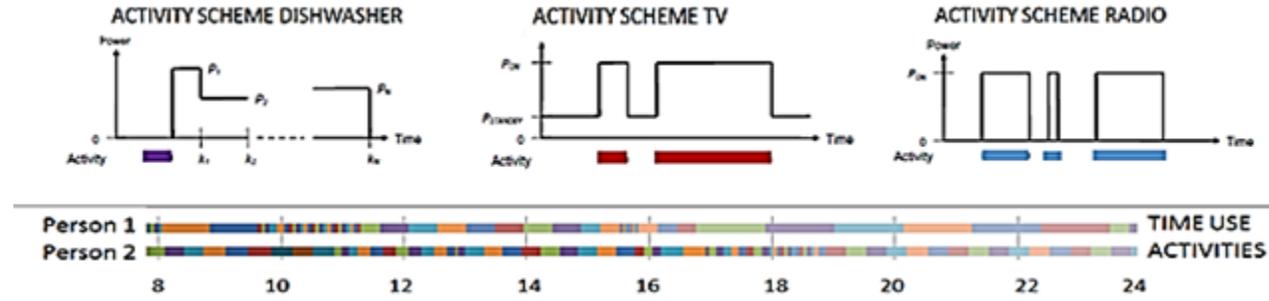
Comparison of peak-time and non-peak time activities for parameter:



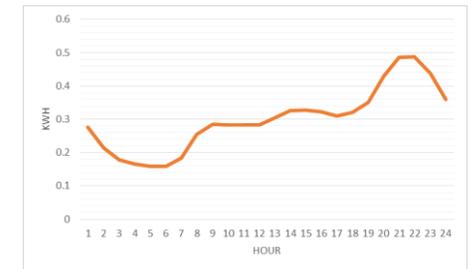
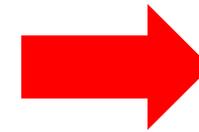
|                   |       |       |       |      |       |      |       |       |       |       |        |       |       |       |       |       |       |       |       |       |       |
|-------------------|-------|-------|-------|------|-------|------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Single            | 27.29 | 26.25 | 28.46 | 0.21 | 28.99 | 2.09 | 29.88 | 30.69 | 21.16 | 3.46  | 29.21  | 26.35 | 22.79 | 25    | 16.81 | 27.72 | 34.02 | 30.53 | 21.69 | 2.22  | 31.51 |
| M/C w chldrn      | 17.46 | 16.23 | 19.78 | 7.52 | 18.89 | 1.97 | 20.32 | 13.86 | 15.34 | 1.29  | 16.29  | 16.48 | 13.24 | 13.71 | 24.37 | 15.84 | 17.53 | 22.11 | 16.87 | 1.05  | 21.34 |
| M/C wo chldrn     | 29.24 | 30.87 | 30.08 | 9.61 | 28.66 | 2.46 | 25.1  | 27.23 | 32.28 | 2.84  | 29.78  | 27.52 | 36.24 | 33.87 | 32.77 | 23.76 | 23.71 | 21.05 | 37.35 | 3.92  | 21.42 |
| SP w chldrn       | 4.877 | 4.354 | 4.336 | 6.25 | 4.235 | 3.39 | 5.179 | 5.446 | 5.82  | 4.694 | 6.18   | 5.39  | 4.412 | 5.645 | 4.202 | 8.911 | 5.155 | 7.368 | 7.229 | 1.387 | 1.17  |
| SP wo chldrn      | 2.857 | 3.562 | 3.252 | 4.17 | 2.932 | 2.14 | 3.984 | 1.485 | 2.846 | 3.333 | 2.809  | 3.36  | 4.412 | 2.419 | 1.681 | 2.97  | 1.031 | 1.053 | 2.41  | 1.387 |       |
| M/C in complex hh | 8.645 | 9.103 | 6.775 | 6.47 | 8.469 | 1.55 | 6.387 | 9.901 | 9.524 | 1.67  | 7.865  | 8.26  | 7.353 | 5.645 | 10.08 | 6.931 | 10.31 | 7.368 | 4.819 | 1.37  | 5.35  |
| SP in complex hh  | 5.616 | 5.145 | 3.794 | 5.2  | 4.886 | 8.37 | 3.984 | 6.436 | 7.407 | 3.71  | 6.18   | 6.1   | 7.353 | 10.48 | 5.042 | 8.911 | 4.124 | 7.368 | 3.614 | 1.387 | 8.75  |
| Other             | 2.96  | 3.166 | 2.71  | 2.3  | 2.606 | 3.39 | 1.992 | 2.97  | 4.762 | 3.71  | 0.5616 | 1.42  | 2.206 | 1.613 | 5.042 | 4.95  | 3.093 | 1.053 | 4.819 | 3.75  |       |

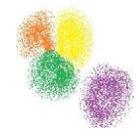


# From time use data to load profiles

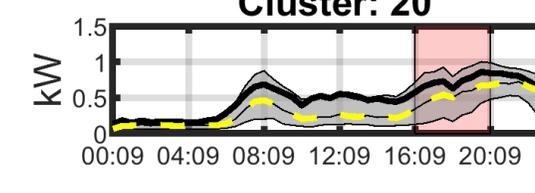
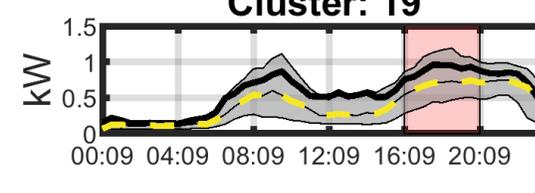
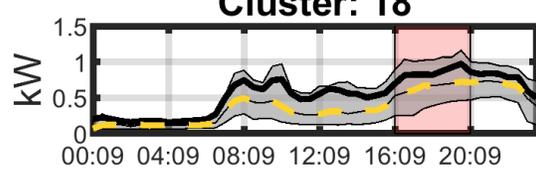
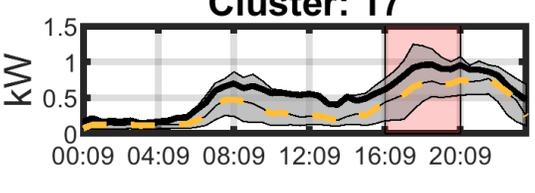
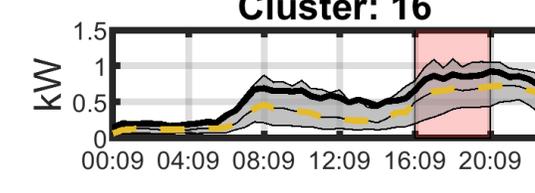
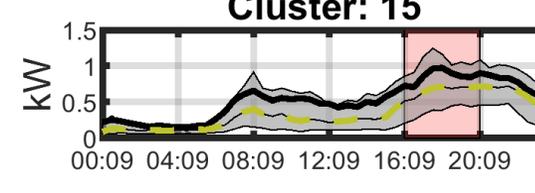
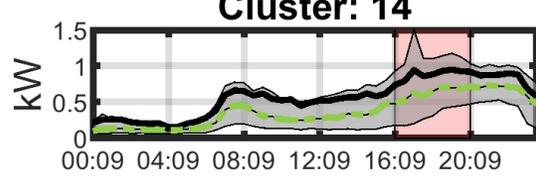
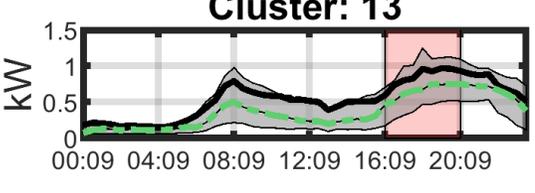
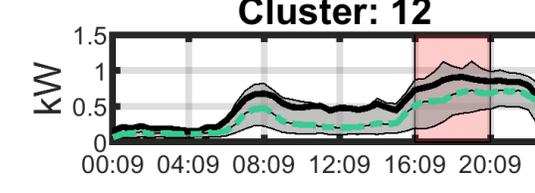
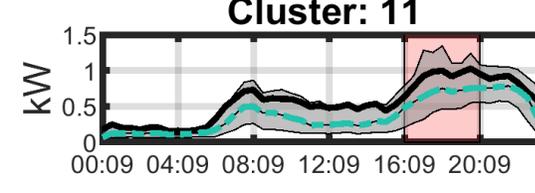
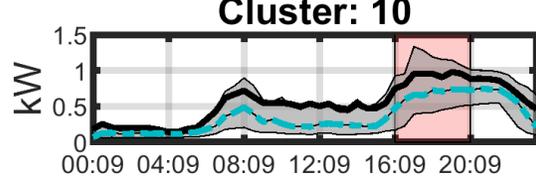
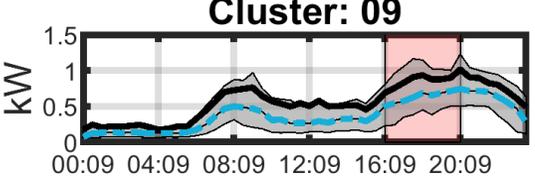
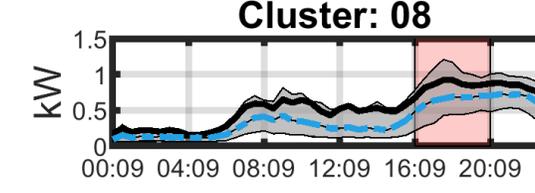
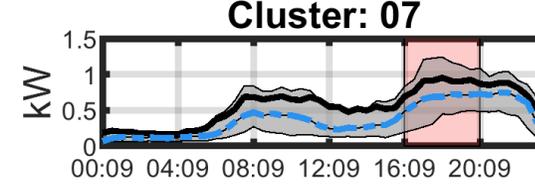
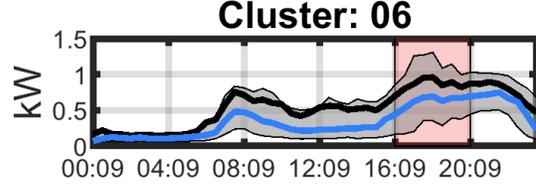
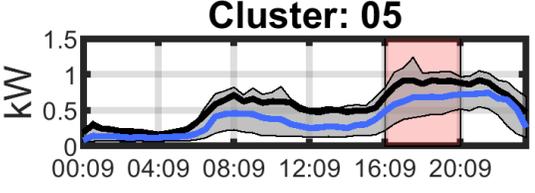
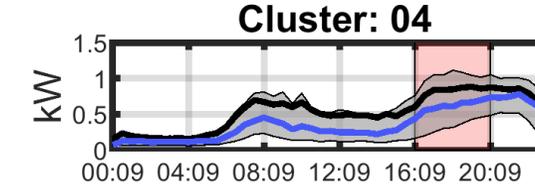
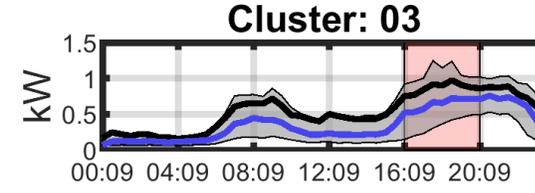
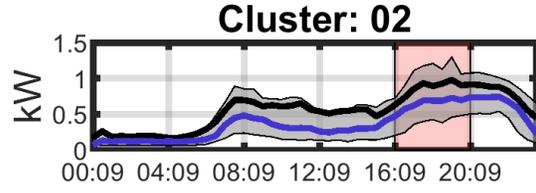
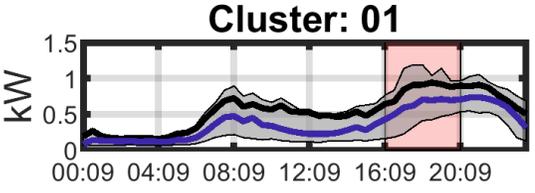


Activity schemes can enable to link time use activities with appliance and electricity use

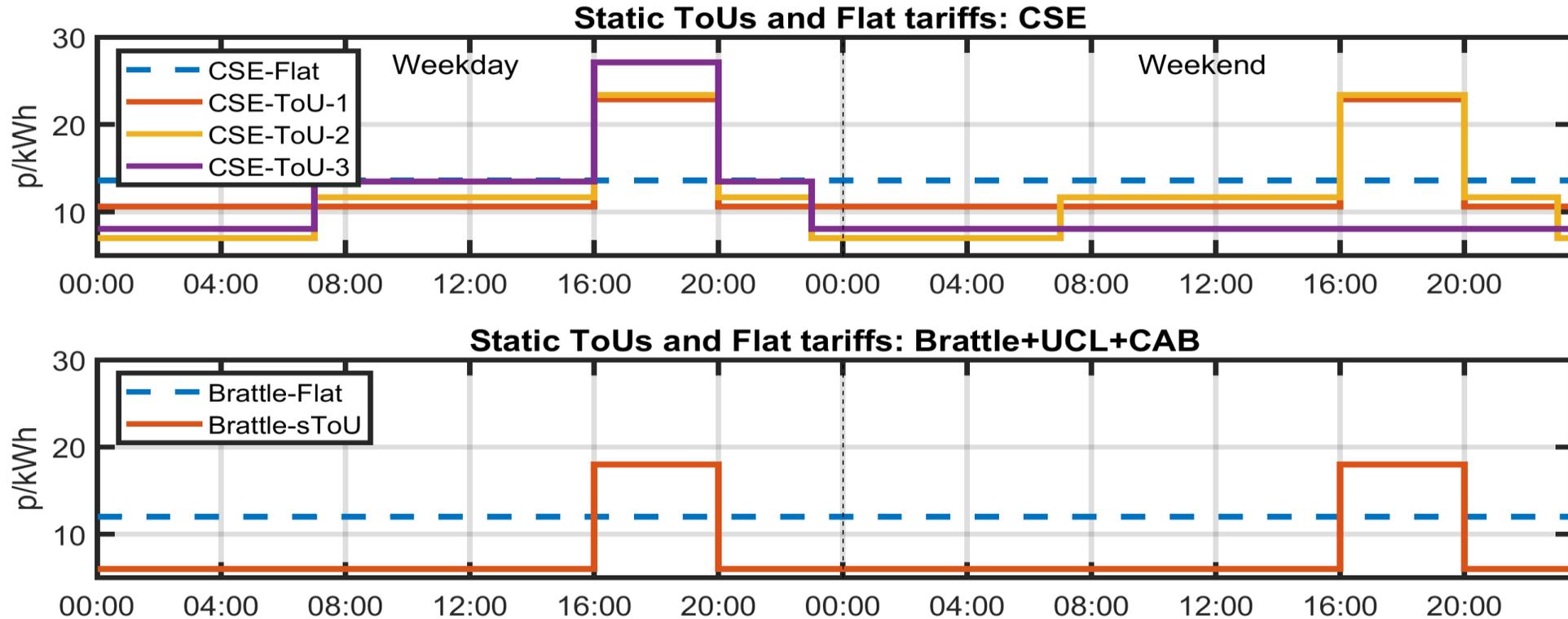




# Demand profiles



# Applying Time of Use tariffs



CSE - Centre for Sustainable Energy. 2014. "Investigating the Potential Impacts of Time of Use (ToU) Tariffs on Domestic Electricity Customers: Smarter Markets Programme."

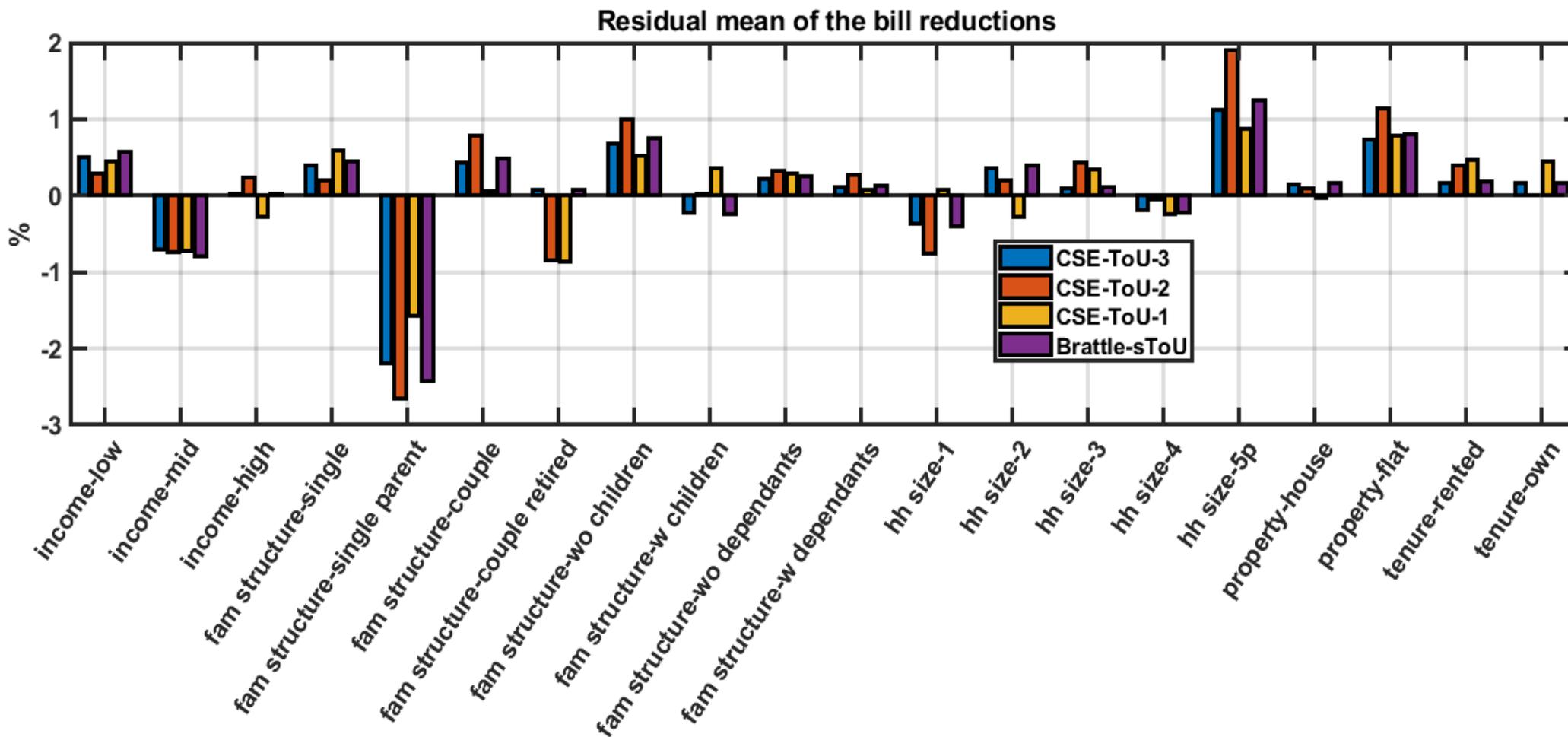
Brattle +UCL - Hledik, Ryan, Will Gorman, Nicole Irwin, Michael Fell, Moira Nicolson, and Gesche Huebner. 2017. "The Value of TOU Tariffs in Great Britain : Insights for Decision-Makers." Vol. I.



# Impact of Time of Use tariffs

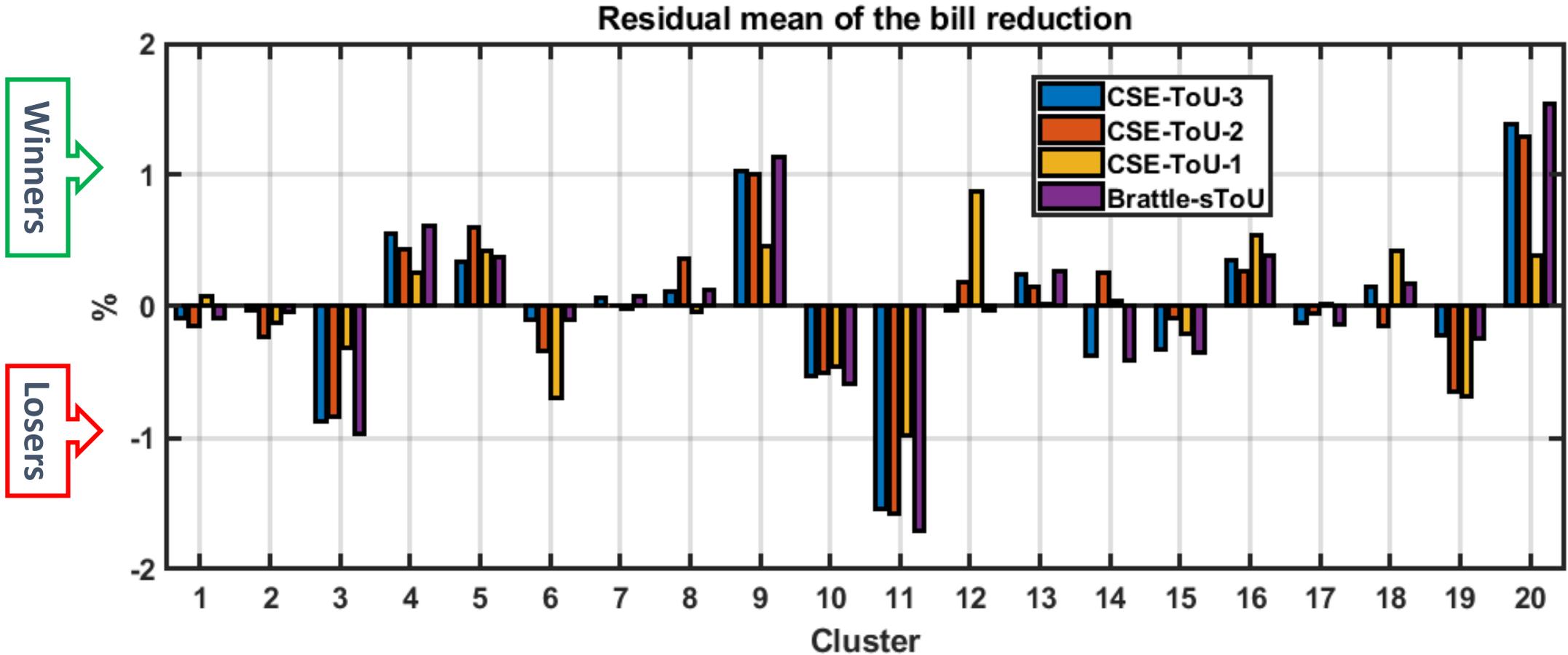
Winners

Losers





# Impact of Time of Use tariffs

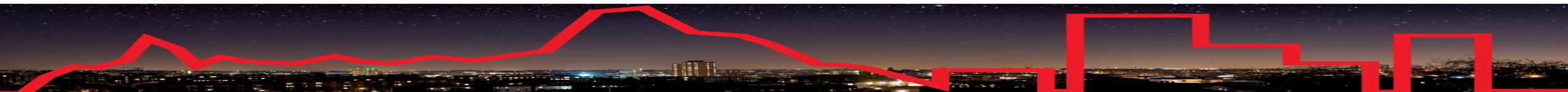


Power to the (flexible) people?  
What happens to those who do not have  
the time and means for demand-side  
flexibility?

Time and non-energy arrangements

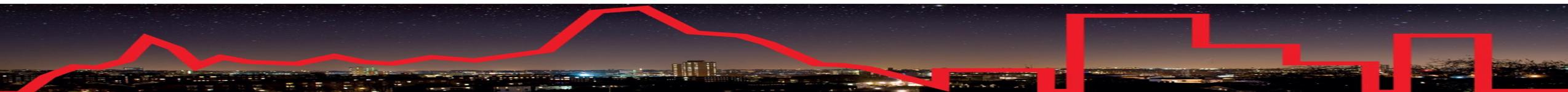
## The single mother nurse

- **Protecting her from flexibility costs?**
- **Excluding her from flexibility opportunities?**



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- Santiago, I., Lopez-Rodriguez, M. A., Trillo-Montero, D., Torriti, J. and Moreno-Munoz, A. (2014) Activities related with electricity consumption in the Spanish residential sector: variations between days of the week, Autonomous Communities and size of towns. *Energy and Buildings*, 79. pp. 84-97.
- Torriti, J., Hanna, R., Anderson, B., Yeboah, G. and Druckman, A. (2015) Peak residential electricity demand and social practices: Deriving flexibility and greenhouse gas intensities from time use and locational data. *Indoor and Built Environment*, 24, 891-912.
- Torriti, J. (2012) Demand side management for the European Supergrid: occupancy variances of European single-person households. *Energy Policy*, 44. pp. 199-206.
- Torriti, J. (2014) A review of time use models of residential electricity demand. *Renewable and Sustainable Energy Reviews*, 37. pp. 265-272
- Torriti, J. (2017), Understanding the timing of energy demand through time use data: Time of the day dependence of social practices. *Energy Research & Social Science*, 25, 37-47.
- Yunusov, T., Lorincz, M. J. and Torriti, J. (2018) Role of household activities in peak electricity demand and distributional effects of Time-of-Use tariffs. In: British Institute of Energy Economics 2018, 18-19 September 2018, Oxford, UK.



# THANKS

